THE LIBRARY OF CONGRESS

AUTOMOBILE CONSTRUCTION AND REPAIR

A PRACTICAL GUIDE TO THE DESIGN, CONSTRUCTION, AND REPAIR OF AUTOMOBILE MECHANISMS

BY

MORRIS A. HALL

Editor, *Automotive Engineering*; Formerly Managing Editor, *Motor Life*; Editor, *The Commercial Vehicle*, etc.; Author of "What Every Automobile Owner Should Know." Member, Society of Automobile Engineers; Member, American Society of Mechanical Engineers

ILLUSTRATED

AMERICAN TECHNICAL SOCIETY
CHICAGO
1919

TL205
.H3
1919

COPYRIGHT, 1919, BY
AMERICAN TECHNICAL SOCIETY

COPYRIGHTED IN GREAT BRITAIN
ALL RIGHTS RESERVED

OCT 21 1919

©CLA536276

INTRODUCTION

THE modern automobile is mechanically a fine piece of engineering and it represents in its development the product of the best technical brains of the country. The engine has changed from the halting, wheezy, unreliable contraption of fifteen years ago into a perfectly dependable, well-behaved, and sweet-running mechanism which carries its owner at high or low speed, in the heat of summer or the cold of winter, over all sorts of road with exceedingly rare periods of distress or failure. The same evolution has taken place with each part of the automobile until practically all the changes in present-day models are simply refinements of the existing mechanisms. No expenditure of money or skill has been spared to make the automobile as near perfect as possible. As a result, it stands today one of our best examples of well-rounded development, a device which has had more to do with our progress in production manufacturing in the last ten years than any other single machine which could be mentioned. Therefore, it behooves those who are interested in this development to study the construction and design factors with great attention. Lessons are to be learned from the evolution of this device, from the failure of that design, and the study of "near perfection" is always profitable.

¶ This volume has been designed not only for the man who is interested in things mechanical, but more especially for the designer, for the mechanic who is engaged in automobile construction and repair work, and for owners and chauffeurs who wish to be their own repairmen. The discussion of the construction of valves, clutch, transmission, etc., is confined mainly to the standard types without much attempt to trace the historic background. As to the repair sections, there are many ways of effecting repairs on an automobile, but the advice here given is based on careful observation and broad experience. The suggestions range from the engine to the differential, from the steering gear to the tires. The exceptionally full section on carburetors and carburetor adjustments and the section on tire vulcanizing, with the description of proper tire repair methods, will be found especially helpful. No attempt has been made to cover "Ignition, Starting, and Lighting Systems," as this has received an exhaustive treatment under that title issued by the same publishers.

CONTENTS

Page

Engine group 11
- General engine features 15
- Cylinder forms and construction 22
- Pistons and accessories 48
- Connecting rods 61
- Crankshafts 72
- Crankcases 84

Carburetors and carburetion 99
- Function of carburetor 99
- Effect of heavier fuels 99
- Classification 101
- Throttle valves 103
- Carburetor operation 112
- Kerosene and heavy fuel carburetors 180
- Carburetor troubles and remedies 194

Inlet manifold design and construction 205
- Changes in design 205
- Heating the charge 209
- Inlet manifold troubles 210

Fuel supply 211
- Tank placing 211
- Fuel feeding 211
- Piping and connections 216
- Reserve tank 217
- Fuel system troubles and repairs 218

Valves and their mechanism 227
- Valve features 227
- Poppet-valve gears 232
- Repairing valve parts 252

CONTENTS

Page

Valves and their mechanism (continued)

Sliding sleeve valves.......... 271
Rotating valves.......... 278
Exhaust system.......... 279

Cooling systems.......... 286

Water cooling.......... 286
Air cooling.......... 300
Troubles and adjustments.......... 302

Lubrication system.......... 305

Motor lubrication.......... 305
General lubrication.......... 321
Oils and greases.......... 322
Lubrication troubles and remedies.......... 325
Bearings.......... 330

Flywheel sub-group.......... 337

Characteristics of flywheel.......... 337
Methods of fastening flywheel.......... 339
Flywheel markings.......... 339

Clutches.......... 351

Cone type.......... 352
Contracting-band type.......... 354
Expanding-band type.......... 355
Disc type.......... 356
Magnetic type.......... 364
Clutch operation.......... 366
Clutch troubles and remedies.......... 370

Transmissions.......... 380

Sliding gears.......... 381
Individual clutch.......... 395
Planetary gears.......... 399
Friction disc.......... 401
Troubles and repairs.......... 409

Gears.......... 421

Types of gear-cutting machines.......... 421
Types of gears in automobiles.......... 428

CONTENTS

Page

Steering group 445

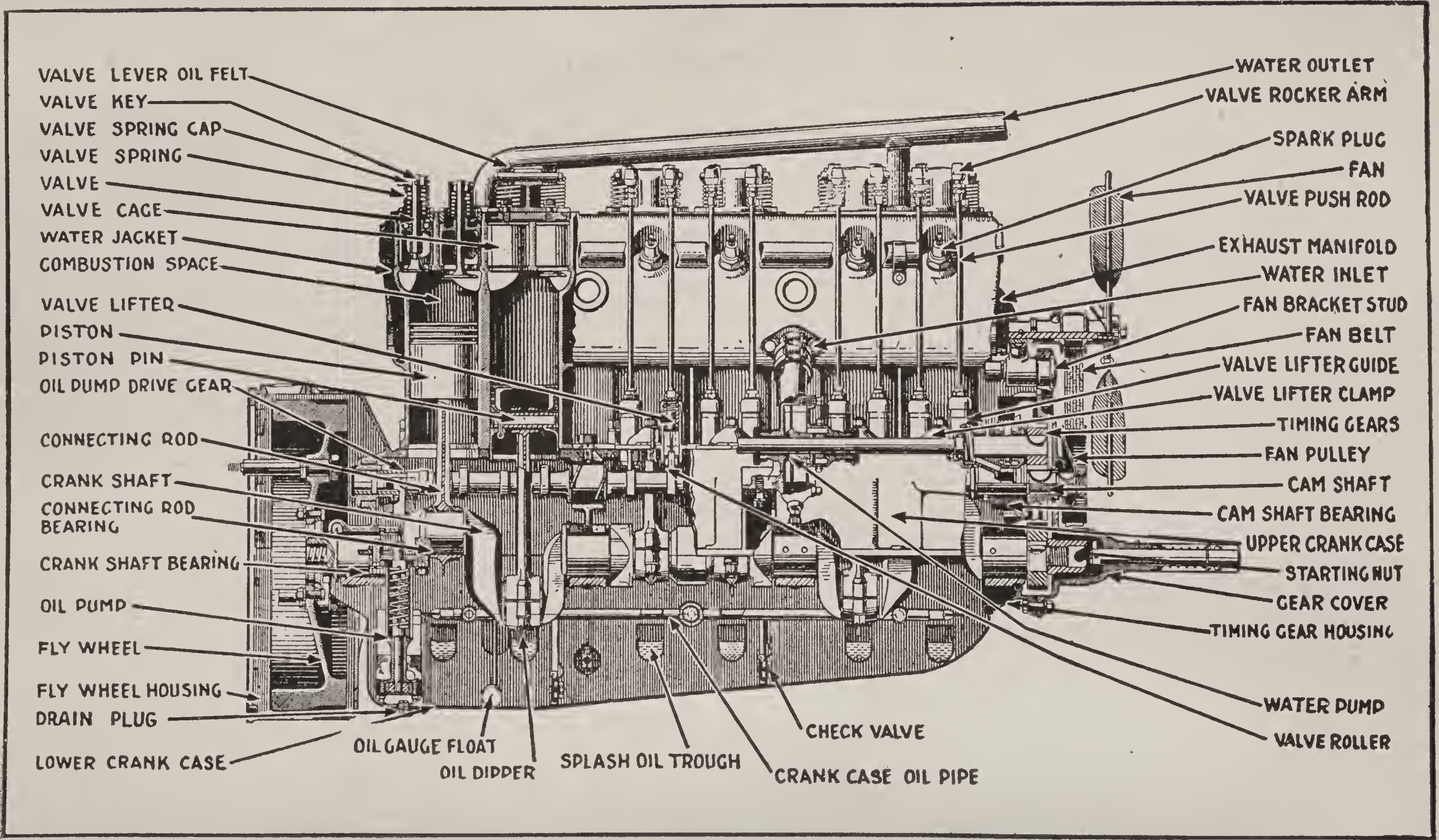
- Steering gears 445
- Steering wheels 470
- Steering rods 474
- Front-wheel drive 480
- Four-wheel drive 482
- Electric drive 489
- Front axles 491

Chassis group 508

- Frames 509
- Springs 530
- Shock absorbers 549

Final-drive group 569

- Rear axle 581
- Brakes 604
- Wheels 622
- Tires 645
- Rims 654



SECTION OF BUICK SIX-CYLINDER ENGINE ON 1918 CAR
Courtesy of Buick Motor Company, Flint, Michigan

GASOLINE AUTOMOBILES

PART I

INTRODUCTORY

Of all the applications of the internal-combustion motor, it is safe to say that none is more important than that applied to the propulsion of the modern motor vehicle—the automobile—which nowadays throngs the roads and streets of nearly every country in the world, and serves a myriad of utilities as they never have been and never could be served by animal transportation.

Standardized, inexpensive to buy, and inexpensive to operate, almost unfailingly reliable, and proved capable of use in the hands of even the most unmechanical of operators, the automobile is at last coming fully into its own. Its design has become recognized as a branch of engineering by itself, its manufacture constitutes one of the greatest of the mechanical industries, and its use is a common necessity.

Naturally, in so tremendous a development, there is sustained by the general public every possible sort of relationship with the automobile, from that of the merely casual observer and occasional user, to the more interested owner; and thence on, in ever closer touch with the full significances of this field of engineering, to the high-skilled and well-paid drivers of cars, the experts who repair them, the shopmen who build them, and the engineers and draftsmen who design them.

All along this line there is an increasing need for knowledge—a demand for definite, specific, usable information concerning the science upon which the motor vehicle is based, and the practice upon which its construction and performance are founded.

In no other important field of engineering is there such a lack of correct and authoritative literature as in the automobile field.

This undoubtedly is due to two conditions that have been involved in the rapid growth of the automobile from a mere experiment to an achieved and commercial fact. The first condition is the circumstance that the men who have deeply studied the automobile from an engineering standpoint, and who are best informed about it, have not had the time to place upon paper the facts with which they are acquainted. The second condition—resulting from the rapid development of automobile design and engineering practice has left no time for the establishment of a formulated science, upon which textbooks of a genuine and permanent authority may be based.

What follows will be an advanced and comprehensive treatment of the very latest devices applied in automobile engineering. All are carefully described, their essentials fully analyzed, and their important details fully illustrated.

Historical material of any kind is useless in a work of this sort, which is intended primarily for the man in the shop, who does the actual work of completing the car in the first place, and the man in the garage who keeps it in running order thereafter. It will suffice to say that while most of the worthy efforts and early progress in the development of the explosion motor and the automobile were made abroad, American designers and American workmen have since shown the way in this field to the whole world, so that today we import a negligible number of motors and cars, while we export to every other country of the world.

GENERAL OUTLINE OF MOTOR-CAR CONSTRUCTION

In general, all motor cars follow along the same broad lines. So much has this become the case in the last few years that a large number of the parts, units, and accessories entering into the construction of the car have become standardized and may, to a certain extent, be taken off one car and placed on another without extensive alteration. This has been done, too, without interfering in any way with the initiative of the various designers.

Groups and Parts. Practically all modern gasoline motor cars may be divided, in a mechanical sense, into six groups of parts or units. These are: (1) the engine, or power-producing group; (2) the clutch group, needed, as will be explained later on, with all forms of explosion motor; (3) the transmission, or gearset, for producing the various car speeds and different powers, while the engine gives a practically constant speed and power output; (4) the final drive group, which connects the speed variator or transmission with the rear wheels, and thus propels the car. Of necessity, this includes the rear axle, while the front axle is usually grouped with the rear; (5) the steering device, for controlling the direction of motion; and (6) the frame, upon which all these and their various accessories are hung, with the springs for suspending the frame upon the axles of the car. There is, of course, a seventh group, the body, but that need not be discussed here, since reference is now made only to the mechanical parts.

Engine Group. In the large diagram of a modern motor car, Fig. 1, the sectional side view is shown above, and the plan view below. In this, note that the engine is placed at the front of the outfit. This is now the position nearly all modern motor car manufacturers use. A few cars have the motor located on the rear axle to save the parts necessary for connecting the two, while formerly the middle position was a favorite one. The purpose of the engine is to generate the power. This is done by the drawing-in, compressing, and exploding of gas produced from gasoline.

Cylinder and Crankshaft Sub-Group. All this work is actually done within the *cylinder,* which really forms the basic working medium of the engine. The actual drawing-in of the gas, its compression and explosion are accomplished by the movements of the *piston* up and down in the cylinder bore. The piston is moved upward and downward by the rotation of the *crankshaft* except when the explosion reverses the situation, and the piston moves the crankshaft, to which it is attached by means of the *connecting rod.* The piston is made to fit tightly in the cylinder by means of *piston rings,* which are compressed into slots formed in the outside of the piston for this purpose. The connecting rod is forced to rotate by its attachment at the lower end to one of the *crankpins* of the crankshaft, which is held in the *crankshaft bearings* fastened in the *crankcase.* It is enabled to turn slightly at the upper, or piston, end by being pivoted on the *piston pin* or *wrist pin.* For convenience the crankcase is usually made in two parts, called the upper and lower *halves.* Sometimes the cylinder is also made with a removable *cylinder head,* or a smaller removable *cylinder cover.* The majority of modern motors have the valves enclosed by removable cylinder *valve covers.*

Carburetion Sub-Group. The production of the gas necessitates what is called a *carburetor,* a good-sized *fuel tank,* and piping to connect the two. The fuel is not always pure and must be filtered through a *strainer*. A cock must be provided in the piping for turning the flow

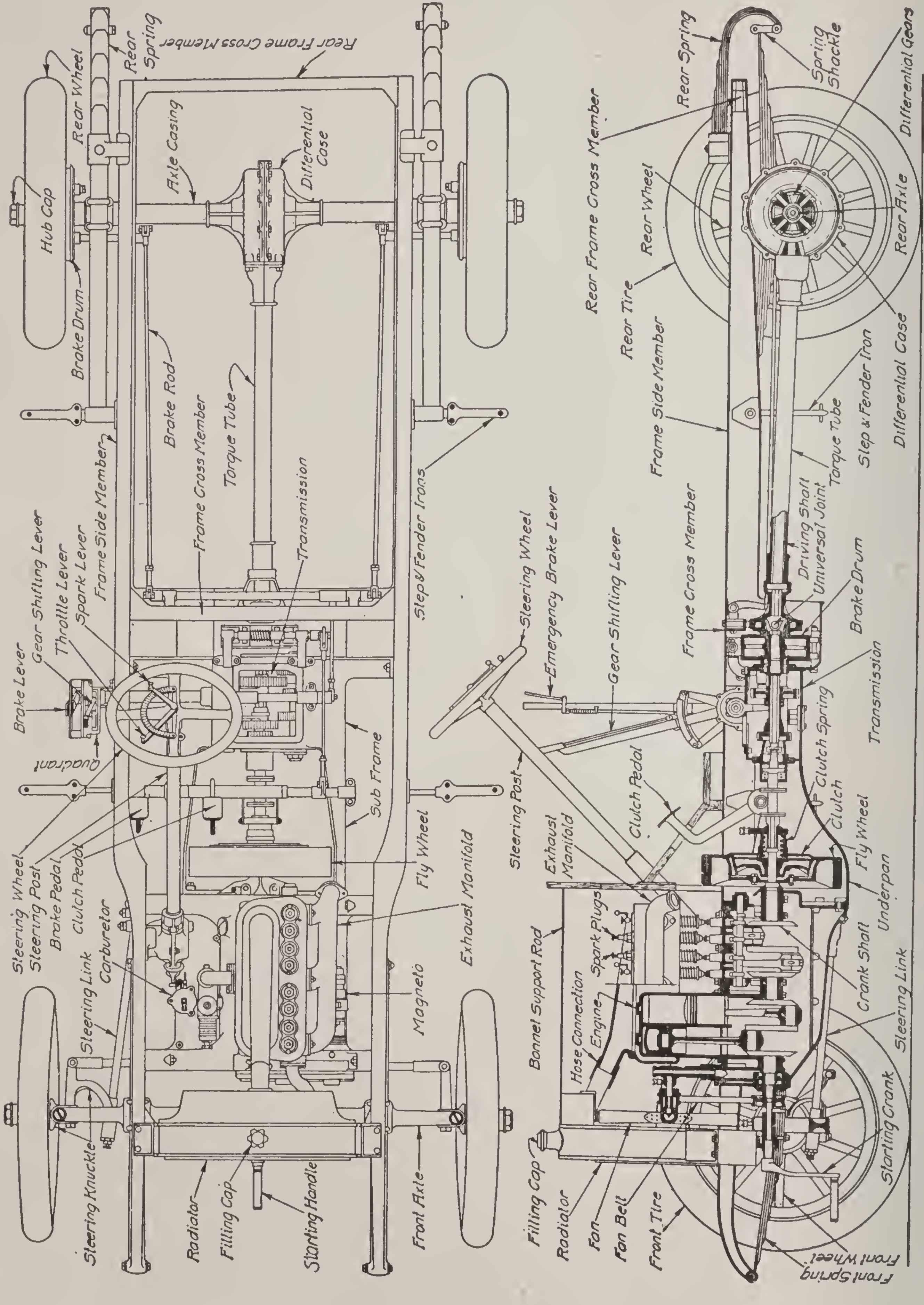


Fig. 1. Side View and Plan of a Modern Motor-Car Chassis, Showing the Various Important Parts, the Location of the Various Groups, and Their Interrelations with Other Groups

of gas from the tank to the carburetor on and off, while the gas produced in the carburetor is taken into the engine through an *inlet* *manifold.* These and other parts, the functions and construction of which will be explained in full later on, constitute the carburetion sub-group.

Inlet and Exhaust Valves. In order to get the gas, which is produced by the carburetion group, into the motor cylinders at the proper time and in the proper quantity, *inlet valves* are necessary. These valves are operated by *cams* on a *camshaft.* The camshaft, which will be explained in detail later, is driven from the *crankshaft* of the engine. After the gas has been admitted into the cylinders, compressed, and exploded, it is of no further use and must be removed from the cylinders. As this must be done at the proper time, and as the proper quantity must be removed, additional valves known as the *exhaust valves* are necessary. These are also operated by cams on a camshaft, driven from the crankshaft.

Exhaust System. The exhaust gases pass from the cylinder through a particular pipe, known as the *exhaust manifold,* and thence to the back of the car. As there remains considerable pressure in these gases when allowed to escape freely, they make much noise and considerable smoke, so that all cars are required by law to carry and use a *muffler.* The exhaust gases pass through this and thence out into the atmosphere. This whole group of parts is called the *exhaust system.*

Ignition System. The *explosion* comes in an intermediate stage. It is produced by means of an *electric spark,* made within the cylinders by means of a *spark plug.* The electric current, which is the original source of this spark, may be produced by a rotary current producer, known as a *magneto,* or it may be taken from a *battery.* In either case, the current must be brought up to a proper strength, and the various sparks must be produced at the exact time they are needed. All this calls for auxiliary apparatus. Moreover, the current producer, if it be a magneto, must be driven from some rotating shaft, and there must be a suitable place provided on the engine to attach it in such a way as to provide for quick and easy removal. All this, as a complete unit, is called the ignition system. A complete treatment of this subject will be found under "Electric Equipment for Gasoline Cars".

Cooling System. A great amount of heat is created by the following explosion and subsequent expanding and exhausting of the gas. Some idea of this may be gained from the two following statements: The explosion temperature often runs up as high as 3000° F., and the exhaust temperature frequently is as high as 1500° F. In order to take away this heat, which communicates itself to the walls and to parts of the engine wherever it comes in contact with them, and, by conduction, to other parts with which it does not contact, the parts which are exposed to the greatest heat are surrounded by hollow passages, called *jackets*, through which water is forced, or allowed to flow. This might be called a collector of the heat, for it is then conducted to the *radiator*, a device for cooling the water. It is there cooled off and then used again. In order to circulate the water, a removable *pump*, driven from some rotating shaft, is used. All this, with the necessary piping to connect the various parts, is called the *cooling system*.

On some cars, notably the Franklin, and on motorcycles, there is another type of engine with an *air-cooled* system. This type will be taken up later.

Lubrication System. To make the various parts rotate within one another, *bearings*, or parts specially designed to facilitate easy and efficient rotation, must be used. In and on all such bearings a form of *lubricant* is necessary, also between all sliding parts. In order to have a copious supply of oil at certain points, various forms of *lubricators* or *oil pumps* are needed to circulate it; pipes must be provided to carry it; a *sight feed*, or visible indication that the system is working, must be placed in sight of the driver (usually on the dashboard); an *oil tank* for carrying the supply must be provided; and a location found for the lubricator or pump, as well as means for driving, removing, adjusting, and cleaning it. All this comes under the head of the lubrication system. This system covers, in addition, isolated points requiring lubrication and the different ways used to supply them.

Starting System. In order to start the engine, a *starting handle* is provided on all older cars, with possibly a *primer* working on the carburetor, and other parts. On modern cars, this work of starting is done by electricity, which requires a *starting motor*, a *battery*, a *switch* for connecting the two, wiring, buttons, and other parts. All this combined is called the *starting system*. For a complete treatment of Starting and Lighting Systems see the article on "Electrical Equipment."

Lighting System. Nearly all modern motor cars have an *electric lighting system.* This includes an *electric-current generator;* a *battery* to retain the electric current until needed; suitable governing devices to control the generation and flow of current; *lamps* to use the current; *wiring* to connect them with the source; *switches* to turn the current on and off; and other parts.

Flywheel. At one end of the engine shaft is the flywheel. This is a large, wide-faced member of metal, comparatively heavy, the function of which is to store energy (by means of rotation) as the engine produces it and to give it back to the engine at other parts of the cycle when energy is needed, and none is being produced. In short, it is a storehouse of energy, absorbing the same from the engine and giving back the excess when it is needed. In general, this effect is greatest when the mass of metal is farthest from the center, consequently flywheels are made of as large a diameter as is possible, considering the frame members. Note this in the illustration, Fig. 1.

Clutch Group. The *clutch* is generally located inside the rim of the flywheel. This is a device, by means of which a positive connection can be made with the engine or a disconnection from it effected at the driver's will. When such disconnection is made with the engine running, it will continue to run idly, and the car will come to a standstill. Conversely, when the positive connection is made, the motor will drive the clutch and such parts beyond it as are connected-up at the time. This arrangement is necessary because of a peculiarity in the gas or gasoline engine which cannot start with a load, but must be started and allowed to get up speed before any load is thrown upon it. The function of the clutch, then, is to disconnect the balance of the driving system from the engine, so that it may attain the necessary speed to carry a load. When this has been done, the proper gear is engaged, the clutch is thrown in, and the engine picks up its load.

Like other groups, this must have a means of connecting and disconnecting, a proper place, proper fastenings, means for adjustment and removal, means for lubrication, and easy access to its parts. All this, collectively, is called the clutch group.

Transmission Group. As has just been pointed out, the gasoline engine cannot start with a load; it must get up speed first. When the load is first applied it must be light. This necessitates certain *gearing,* so that, when starting, the power of the engine may be multiplied many times before reaching the wheels and applied to the propulsion of the car. Furthermore, it has been found convenient to have a series of such reductions or multiplications. These correspond to the various speeds of the car, for, obviously, if the power is multiplied by means of gearing, it is reduced in speed in the same ratio. This whole group of gearing is the *transmission* or *gearset,* and the various reductions are the *low, intermediate,* and *high speed* in a *three-speed gearbox*; and *low, intermediate, second,* and *high* in a *four-speed gearbox.* A gearbox is always spoken of by its number of forward speeds, but there is in all of them, in addition to the forward speeds, a *reverse speed* for backing the car.

In the usual form, these gears are moved or shifted into and out of mesh with one another, according to the driver's needs. For this purpose, *shifting gears* must be provided within the *gearbox,* that is, the arrangement must be such that the proper gears can be moved back and forth, with a *shifting lever* outside for the driver's use, and proper and accurate connections between the two. The gears must be mounted on *shafts,* these in turn on *bearings,* the bearings must be supported in the *gear-case,* and this must be supported on the frame. In addition, there must be suitable provision in the *gear-case cover* for inspection, adjustments, and repairs; all the moving parts must be lubricated; all parts must be protected from the dust, dirt, and moisture of the road, etc. All this comprises the *transmission* or *gearing group,* which properly ranks second to the engine group in importance.

Final Drive Group. *Driving Shaft.* The connection from the transmission to the rear axle in pleasure cars is usually by shaft, called the *driving shaft.* On the majority of motor trucks, however, it is by means of *double side chains,* which will not be discussed here. This shaft is sometimes inclosed in a hollow *torque tube,* with suitable connection at the front end to a frame cross-member, and at the rear to the *axle housing.* Its construction is generally such that it contains a *bearing* for the driving shaft at both front and rear ends. In addition, the majority of final drives contain at least one *universal joint,* and many of them contain two. As its name indicates, this will work universally, that is at any angle, its particular function in the driving shaft of an automobile being to transmit power from a horizontal shaft—that of the engine clutch and transmission—to an inclined one—the driving shaft—with as little loss as is possible.

Rear Axle and Differential. The driving shaft drives the rear axle through some form of gear, either *bevel, worm,* or other variety, and is usually a two-part shaft. The reason for cutting the rear axle is that each wheel must be driven separately in rounding a curve, for one travels a greater distance than the other. This seemingly complicated act is produced by a simple set of gearing called the *differential,* which is located within the driven gear in the rear axle. Each half of this is fixed to one part of the *axle shaft.* All these gears and shafts must have bearings, lubrication, means for adjustment, etc. On the outer ends of the axle shafts are mounted the *rear wheels,* which carry some form of tires to make riding more easy. The *brakes* are generally in a hollow drum attached to the wheels. All this goes to make up the driving system.

Steering Group. The front wheels perform a different function. They are hung on the *steering pivots,* so that they can be turned to the right or the left as desired. In order to have the wheels work together, a rod, called the *cross-connecting rod,* joins them, while the motion is imparted to them by means of another rod, called the *steering link,* which joins the *steering lever* or *arm* with the right-hand, or left-hand *steering pivot.* The last-named lever projects downward for this purpose from the *steering-gear case* and is moved forward and backward by the rotation of the *steering wheel* in the driver's hands.

The transformation of the rotation or turning motion of the hand wheel into a longitudinal movement is accomplished within the steering-gear case by means of a worm and gear, a worm and partial gear, or by a pair of bevel gears. All these parts need more or less adjustment, lubrication, fastening means, etc., the complete group being designated as the steering group.

In addition, the steering wheel and post carry the *spark* and *throttle levers,* with the rods, etc., for connecting them to the igniting apparatus (magneto, timer, etc.) and the carburetor, respectively. The purpose of the spark lever is to allow the driver to vary the power and speed of his engine by an earlier or later spark, according to his driving needs. Similarly, the throttle lever is for the purpose of opening or closing the throttle in the intake manifold of the carburetion system and regulates the amount of gas entering the engine, thereby increasing or decreasing its power output, or speed. Actually, these are parts of the ignition and carburetion systems, respectively, but they are usually classified with the steering group, because they are located on the steering wheel and post.

Frame Group. Little need be said about the frame. The *side members* are generally supported by the *springs* at the front and rear ends. The springs are connected to the axles and support the car. The *front cross-member* usually supports the radiator and sometimes the front end of the engine, too. The *rear cross-member* usually supports the gasoline tank when a rear tank is used. The other cross-members may support the engine, transmission, shifting levers, and other parts, according to their location. In general, the number and character of frame cross-members is slowly changing; the modern tendency is toward their elimination. By narrowing the frame at the front, the engine can be supported directly on the side members. With the units grouped, the same is true of the other important units.

Formerly, practically all motors and transmissions were supported on a *sub-frame*, but it has been found that the same results can be obtained when this extra weight is eliminated. Fig. 1 shows a sub-frame.

When the shifting levers are placed on the outside, they are fastened to the frame, as is the steering gear; all step, fender, and body parts, the *under-pan*, or *splash-pan*, for protecting the mechanism from road dirt; and usually the headlights. The frame is constructed with this idea in view, six bolts generally being used. The muffler is usually hung from a rear-frame member. When electric lighting and starting are used, the battery is very often hung in a cradle, supported by the frame, while the *hood* or *bonnet* is supported equally by the side members of the frame (usually covered with wood), and by a rod running from radiator to dash.

In Fig. 1, it will be noted that the engine group (1) and the clutch group (2) are together, really forming one unit. Back of this the transmission (3) and the rear axle or final drive group (4) form two separate additional units. When the transmission is united with the motor (forming a *unit power plant*) or with the rear axle, one unit is practically eliminated. The different functions of the components are not changed, but the grouping previously pointed out becomes less apparent, for units (1), (2), and (3); or (3) and (4) become one.

ENGINE-GROUP ELEMENTS

GENERAL FEATURES

In the following pages, the general grouping just outlined will be followed consistently, so that the student and worker will be able to follow through the construction and repair of the entire car in a reasonable and logical manner.

The principles of engine design, and the methods and details of engine construction are second to none of the other factors that combine to produce the complete modern automobile.

How automobile engines operate, the reasons underlying the various details of different designs, and the relative merits of different constructions are all too little understood by most of those who have to do in a practical way with the new conveyance.

Cycles of Engine Operation. In all motors of any type other than those in which there is a perfectly continuous development of the power through constantly rotating elements—as in the electric motor and the steam turbine—there must be reciprocating elements that function through indefinitely repeated series of operations. Such a series of operations is termed the cycle of the engine and is abundantly explained later in the book. It will suffice here to call attention to some of the merits and demerits of the different cycles that are in practical use.

Two-Cycle Engines. That type of internal-combustion engine in which every stroke in one direction is a power stroke affords a maximum of power impulses to any given number of engine revolutions, but because of other limitations it is not always possible to make a two-cycle engine run as fast as a four-cycle, so that in the majority of cases, the number of explosions in a given period of time, or for a given vehicle speed, is no greater with a two-cycle than with a four-cycle engine.

In addition to this, most two-cycle engines are often difficult to start. They are likely to be wasteful of fuel, not at all flexible in the matters of speed and pulling power, and in various other respects difficult to apply to automobile service. Their greatest merit is their extreme simplicity.

Four-Cycle Engines. The four-cycle engine is the type by which nine hundred and ninety-nine out of every thousand present-day automobiles are propelled. Varied through an immense number of possible forms, and with minor differences in the product of every maker, its fundamental functioning has, nevertheless, proved to be far the most suitable for automobile propulsion.

With the succession of suction, compression, explosion, and exhaust strokes afforded by the four-cycle motor, a very positive and reliable functioning is secured; and by the expedient of a sufficient cylinder multiplication to afford good mechanical balance and frequent power impulses, its flexibility, durability, and practical quality can be brought to a very high standard in a well-designed and honestly built motor.

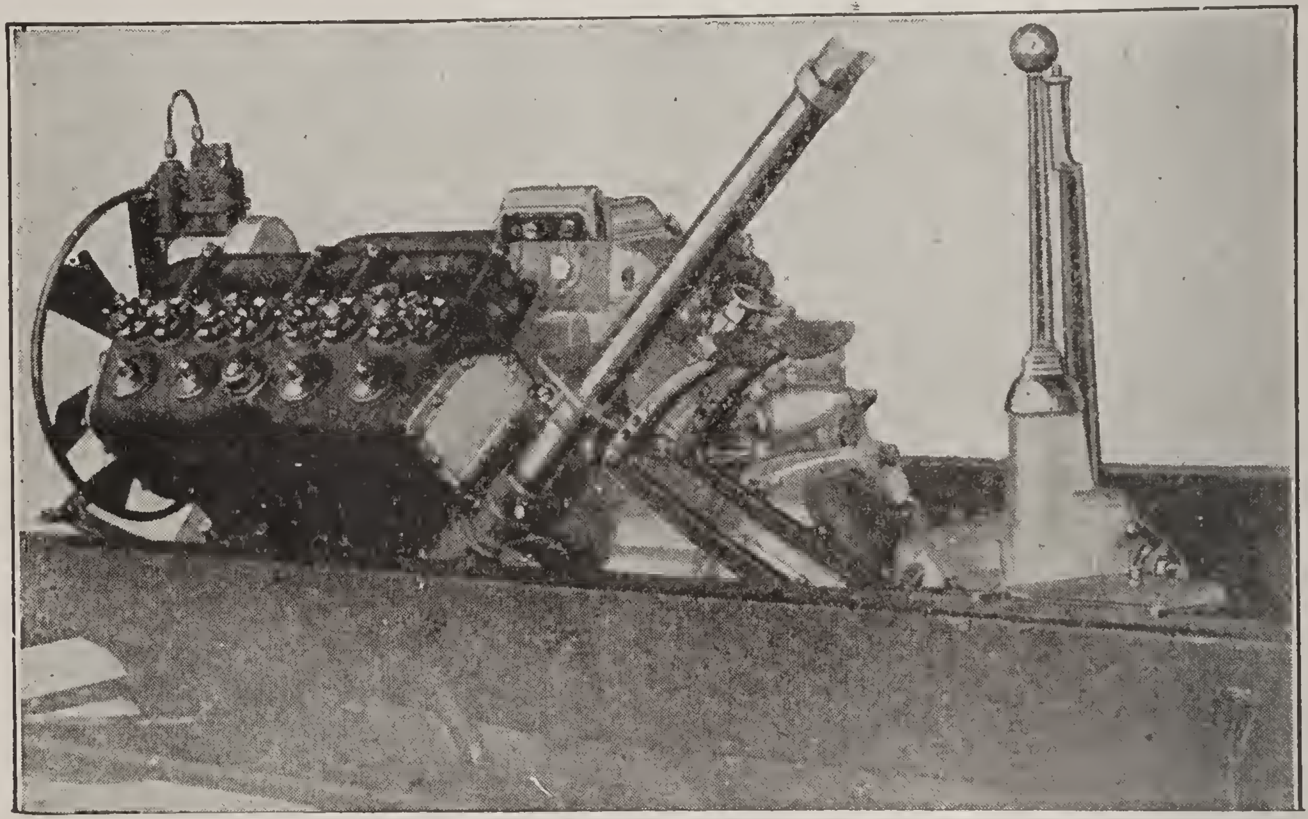


Fig. 2. Eight-Cylinder V-Type Motor of Cadillac Car, Shown Installed in Chassis

At the same time, the fact that so much more attention has been paid to the four-cycle motor than to any of its possible competitors for popular favor, undoubtedly accounts in some measure for its present pre-eminence, and it is an open question with many engineers as to just what virtues might or might not be realized with other constructions, were they as exhaustively experimented with and exploited.

Cylinder Multiplication. There seems to be no reasonable limit to the extent to which cylinder multiplication can be carried in the effort to improve the mechanical balance and to even the torque of gasoline motors. But established practice has, nevertheless, settled upon four-cyclinder vertical engines as those most suitable for the propulsion of the average automobile, as this is the least number of vertical cylinders with which mechanical and explosion balance can be secured.

The use of six cylinders, with the crank throws 120 degrees apart and the explosions occurring once for every 120 degrees of crankshaft rotation, affords a smoother-running motor than the four-cylinder.

Still better than the "six," from every standpoint except that of cost, which has prevented its wider application to automobiles, is the V-shaped, eight-cylinder motor, of the type illustrated in Fig. 2, which gives a good view of the unit power plant of a well-known American machine. In both of these, a four-throw shaft, similar to the ordinary four-cylinder crankshaft, is used, is much cheaper to manufacture than a six-cylinder crankshaft, and the two rows of cylinders, each practically constituting a separate four-cylinder engine, are made to work upon the common crankshaft at 90 degrees apart.

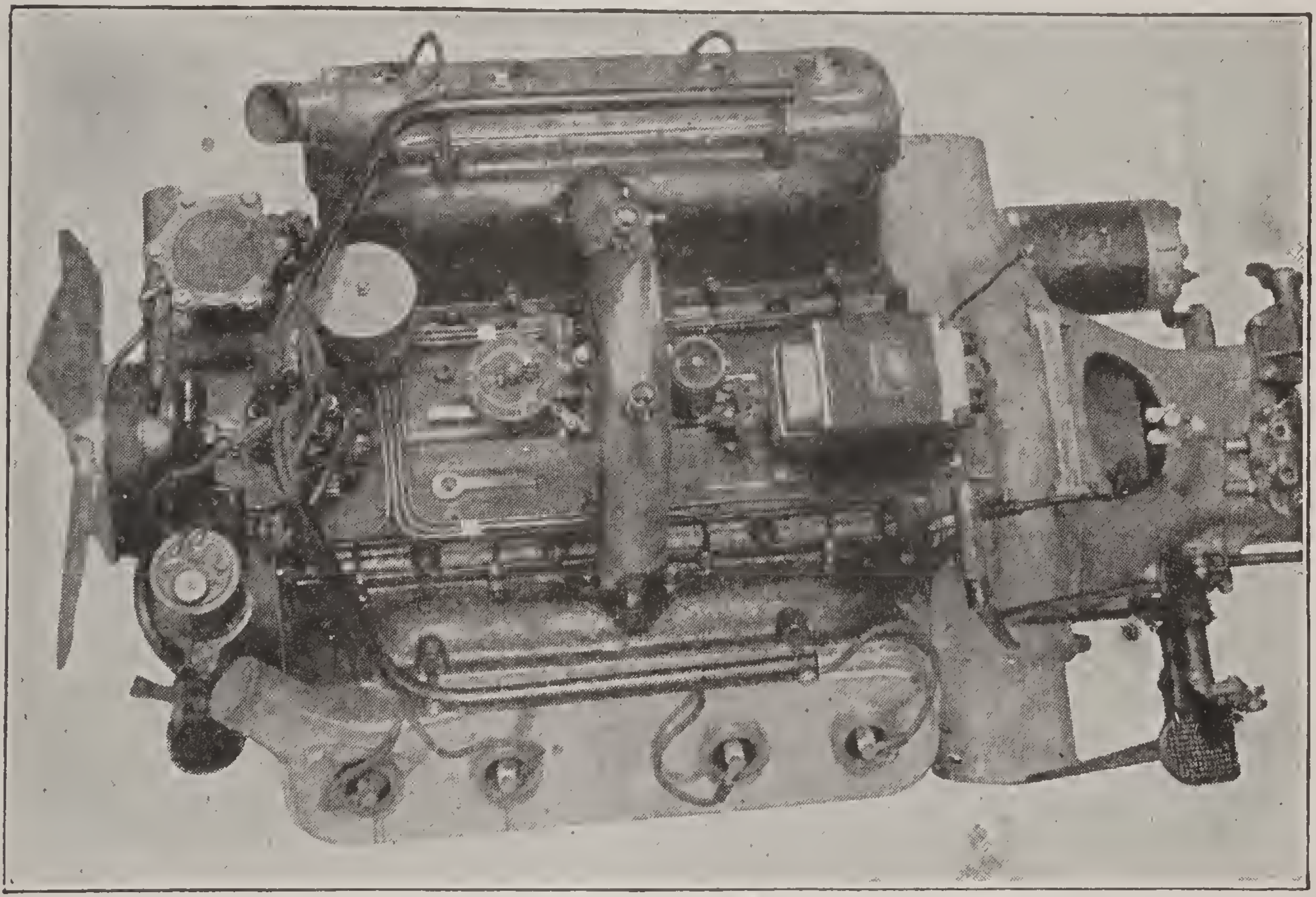


Fig. 3. Overhead View of Stearns-Knight Eight-Cylinder Sleeve-Valve Motor
Courtesy of F. B. Stearns Company, Cleveland, Ohio

The most recent tendency in car motors is toward the eight-cylinder V-type, following the marked success of this form in aviation use.

Not only has the V-form been produced in the poppet-valve form, but also in the Knight sleeve-valve type an example of which is shown in Fig. 3. Furthermore, a considerable number of twelve-cylinder V-type motors have been built, a good example being shown in Fig. 4.

An answer to the demands of the car owners for the flexibility and power of the multi-cylinder types has been recently given by the issue of a very flexible and quick starting four-cylinder motor with 16 valves, two intake and two exhaust valves in each cylinder. Four of these of widely varying design have already been announced—Stutz, White, and Drexel Motor Car Companies, and Wisconsin Motor Company. The details of the Wisconsin motor are given in the section on "Valves". The large increase in the size of the valve openings makes clean mixtures and adequate scavenging easily obtainable, with a corresponding gain in the flexibility and power of the motor.

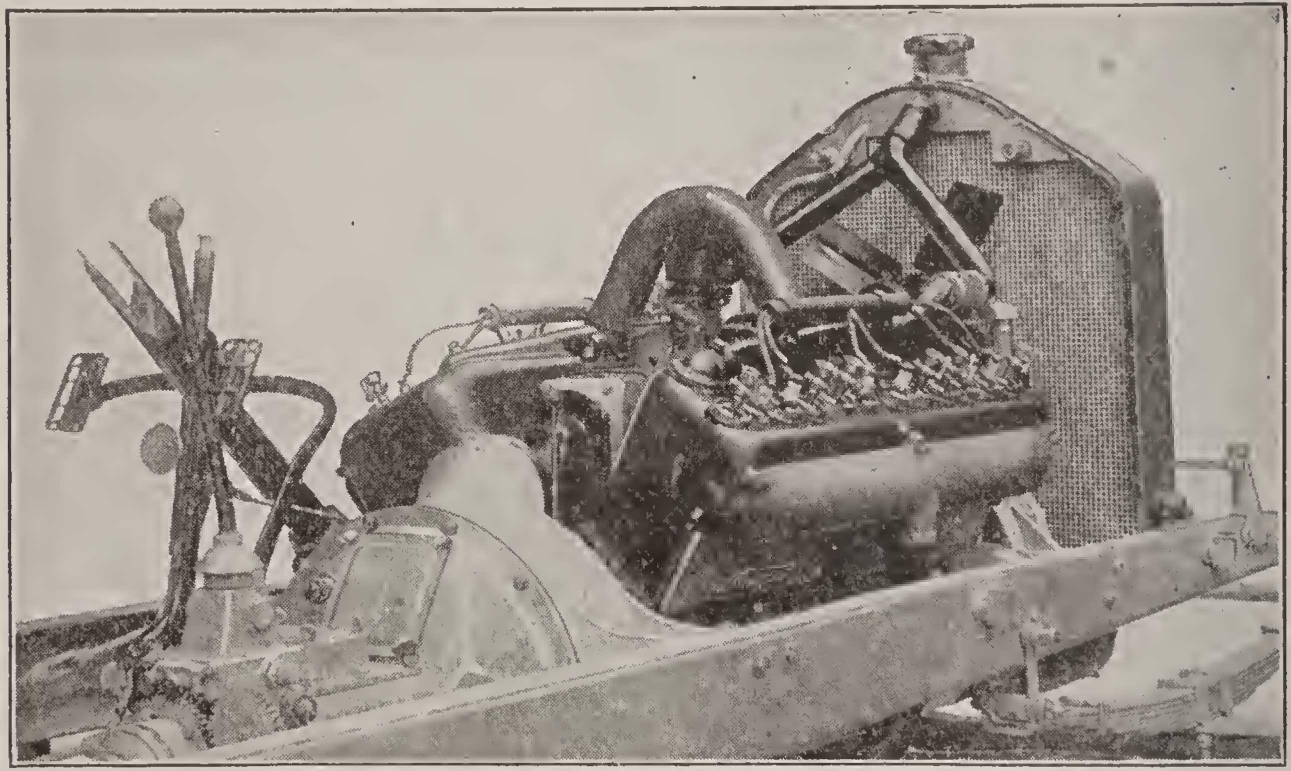


Fig. 4. Side View of National Twelve-Cylinder V-Type Motor
Courtesy of National Motor Vehicle Company, Indianapolis, Indiana

In aviation work, no form of motor has made as great progress as the rotating-cylinder type, which has been built usually with an odd number of cylinders, as five, seven, or nine; or when these are paired with an even number, as ten, fourteen, or eighteen. As yet, this type has not been applied to motor cars, but considering its advantages, it would not be strange to see this done at an early date. These motors have a single-throw crankshaft of very light weight; the rotation of the cylinders at a rapid rate allows of their being air-cooled and also very light in weight, eliminating all of the parts and also the weight in the water-cooling system. The large revolving mass does away with the need for a flywheel, while the practical elimination of reciprocating parts reduces vibration to a minimum.

In the extreme, motors of the V-type have been constructed with sixteen cylinders, eight in each group. These have been very successful in aeroplanes and motorboats, particularly the latter.

GENERAL ENGINE TROUBLES AND REPAIRS

Engine Troubles

Deposits of Carbon in Cylinder. These are loosened by introducing two or three tablespoonfuls of kerosene, put into the cylinder when warm through spark-plug hole. Replace the spark plug, but do not connect up the wires. Turn the engine over slowly to work kerosene back of rings. Allow it to stand a few minutes. Then connect the wires and start the engine running out of doors, as dense smoke will come for a time. Clean spark plugs and replace.

Knocking. Knocking should not be permitted. It is likely to result in injury to the engine. Ordinarily, knocking is avoided by retarding the spark. In starting up a hill where considerable power will be needed, an open throttle with advanced spark should be employed before beginning the climb. Should the motor begin to knock when part way up the hill, the spark should be gradually retarded. Continued pounding is caused by the connecting rod and main-shaft bearings becoming loose.

Failure to Start. Try the following remedies:

See that current is switched on.
See if throttle valve is open.
Be sure gasoline tank is filled.
Be sure gasoline valve is open.
See that air can enter filling cap of gasoline tank.
Flood carburetor.
If weather is cold, prime cylinders by squirting a little gasoline in through each compression relief cock.
See that spark plugs are clean.

Missing of Explosions. See "Troubles with Ignition System."

Popping in Carburetor. Snapping or popping in the carburetor is caused by lack of gasoline, so that the mixture fed to the motor is not rich enough, and as a result it burns so slowly that one of the admission valves may be open before the charge is completely burned, and part of the burning charge is forced back through the pipe leading from the carburetor to the combustion chambers. If adjustment of carburetor is such that a weak mixture should not occur, inspect the gasoline piping system carefully for an obstruction. Popping in the carburetor may also be caused by a leaky joint in the piping and by connections between the carburetor and the combustion chambers.

Poor Compression. Valve stem may be broken and sticking. Valve spring or valve stem may be clogged with dirt. Cylinder or explosion chamber may be cracked. Piston rings may be broken or turned so that cuts line up, allowing pressure to escape. Cylinder may be gummed. Cam may be loose. Water may leak into cylinder through plugs in cylinder head. Valves may not seat properly due to being covered with soot. Valves may have to be reground.

Engine Starts, but Stops, after a Few Revolutions. Engine bearings may have seized from lack of lubricant. There may be too much oil in crankcase. Water may be entering cylinder through cracks or through plugs in cylinder head. Carburetor float may be sticking. Poor water circulation may be due to broken pump shaft or clogged water piping.

Engine Runs Well on Slow Speed but Not on High Speed. Muffler may be stopped up. Carburetor air valve not properly adjusted.

Engine Pulls on High Speed but Not on Low Speed. There may be a leak in the inlet pipe. Carburetor adjustment not proper.

Knocking Continues Even after Spark Is Properly Adjusted. There is a possibility of the flywheel being loose, of loose or worn bearings in the engine, or of something broken inside the engine.

Repairs

General Instructions. By far the most important part of the car is the engine, and this should, therefore, receive the greater portion of the time and attention during any repair or overhaul work, even by going so far as to take it out of the chassis if the trouble is at all serious. For this purpose, all ignition wires and carburetor and magneto operating rods are detached. Next, the various manifolds are removed, the water system is drained, and all hose connections are broken. Usually it is necessary also to take the radiator

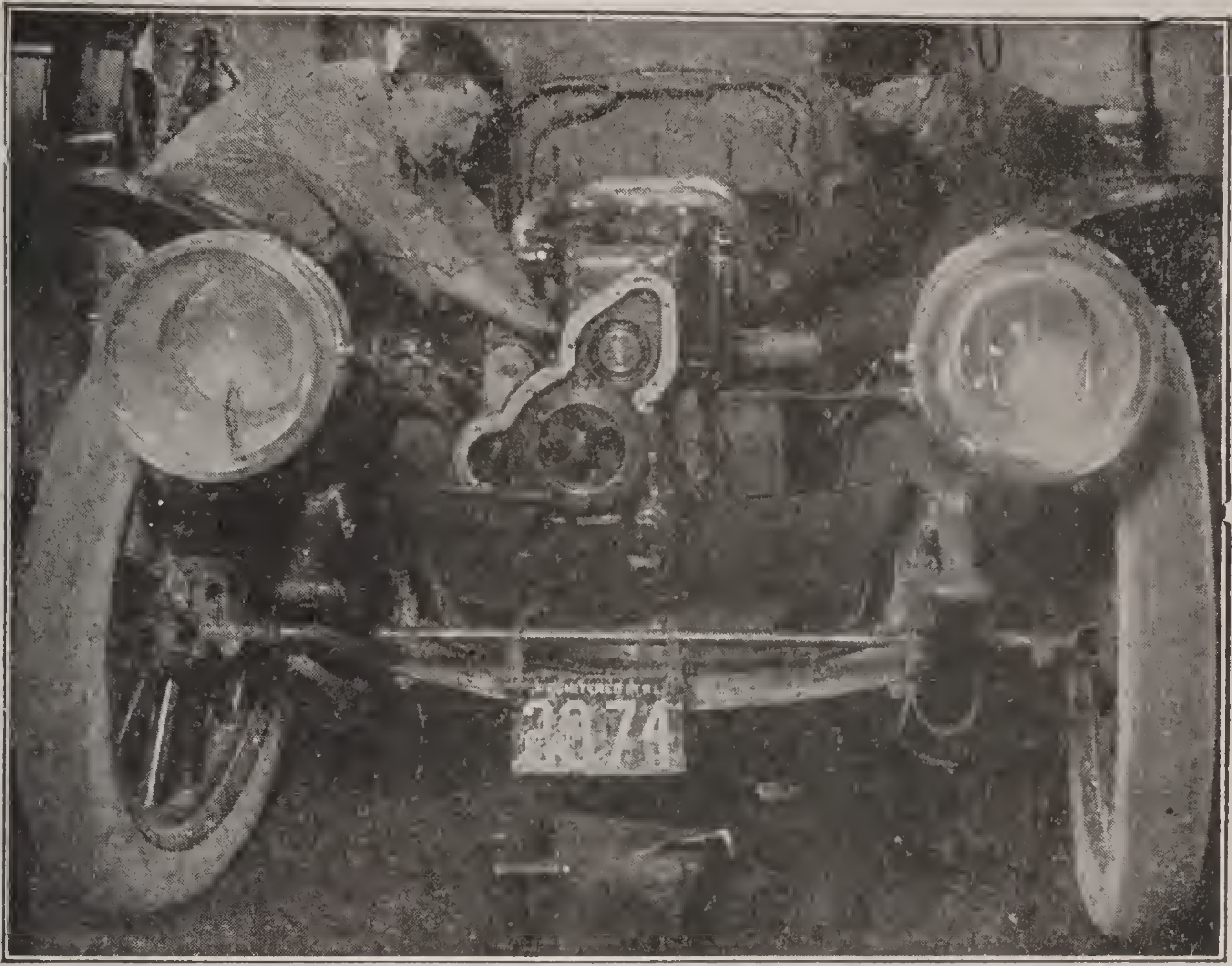


Fig. 5. Dismounting Engine for Repair

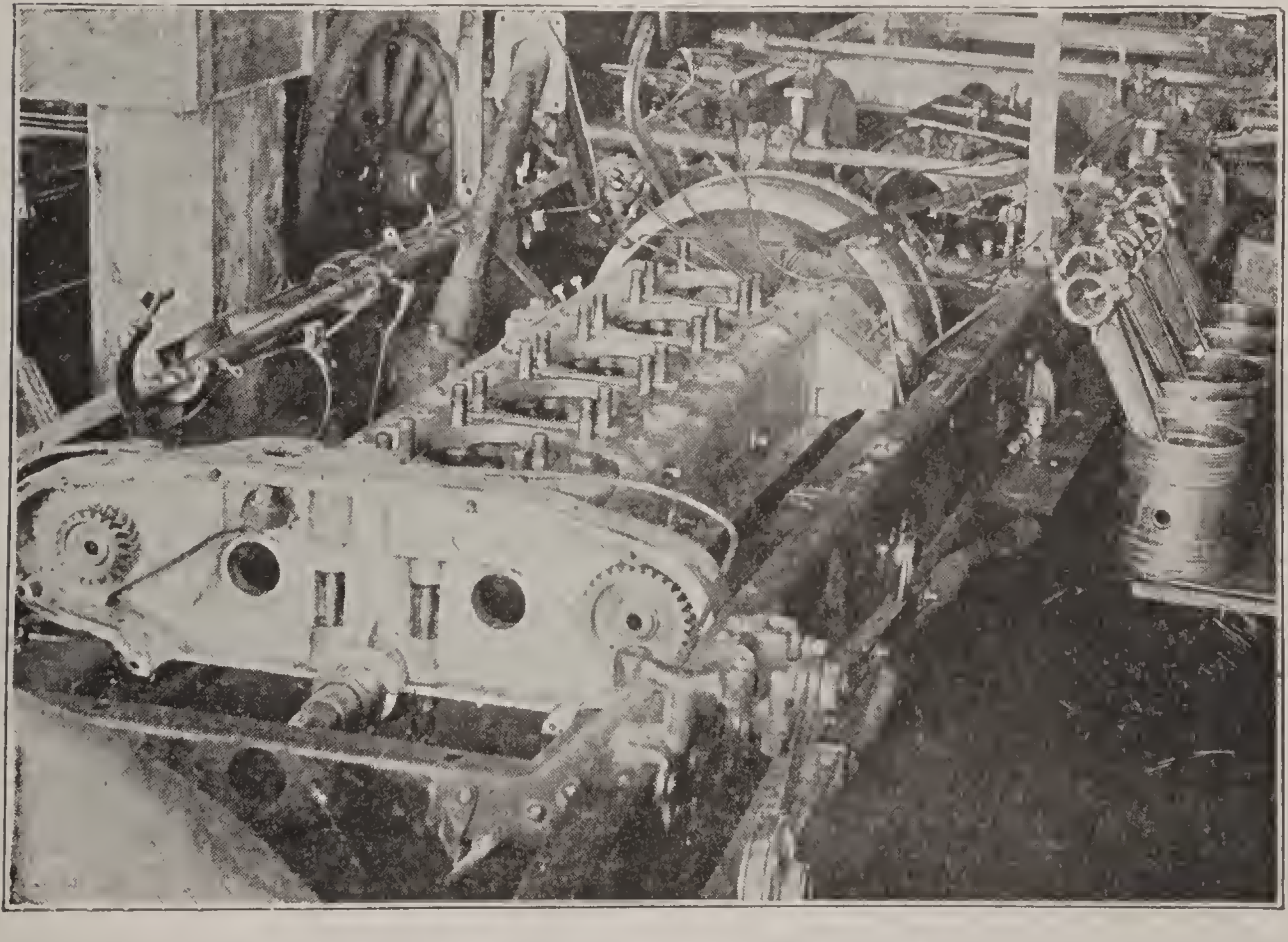


Fig. 6. Engine Dismounted, Showing Cylinders Removed

off. When this is done, the appearance of the vehicle and of the work is very much like that presented in Fig. 5, which shows two men engaged in loosening up certain parts of the engine preparatory to taking it out.

When all accessories have been removed or loosened up, the holding bolts are taken out, the clutch disconnected, and the motor is left free to be swung out by means of a small crane or hoist. In some cases, the work can be completed without disturbing the base of the motor, as in Fig. 6, which shows a big car partly disassembled for repairs, the radiator and cylinders having been removed at this stage. The trouble here was found within the cylinders, hence, as soon as they had been removed, the balance of the six-cylinder motor and its chassis could remain undisturbed.

Hoists and Cranes. *Yale & Towne Form.* For lifting out an engine or other unit approximating several hundred pounds (possibly 500 pounds in the case of a big engine) an efficient form of overhead hoist is needed. There is nothing better than the Yale & Towne triplex hoist, although this is not a cheap form. It can be attached to any channel or I-beam built into the roof of the building, or if that is impossible, it can be hooked into any wire or rope loop over a ceiling beam. It multiplies the power which one man can apply to such an extent that one man can lift out a 500-pound engine with it very readily.

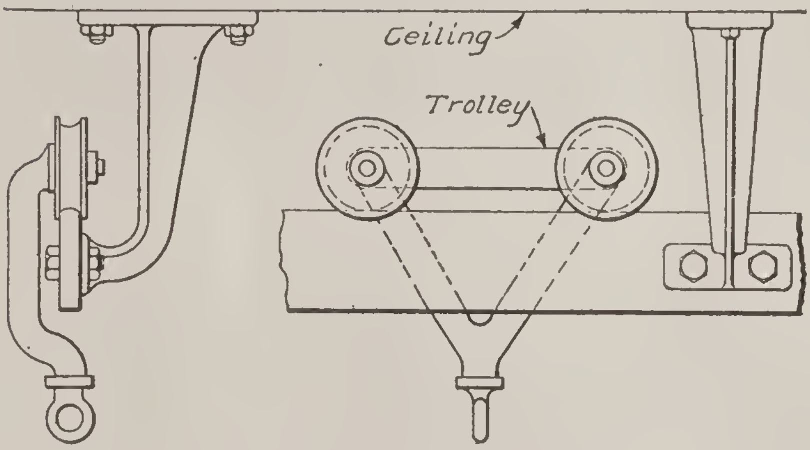


Fig. 7. Method of Constructing Track Attached to Ceiling of Shop

Home-Made Ceiling Hoist. Lacking one of these, a substitute can be made as indicated in the sketch, Fig. 7. The track is plain rectangular metal, known as ½ inch by 2 inches flat, while the brackets supporting it can readily be forged by any good blacksmith. The trolley consists of a forged and bent arm for one side and a straight bar for the other. The wheels can be found in any hardware store. The bottom end should be drilled and tapped, and the ring made in the lathe to fit into it. For this purpose, the threads should be large and numerous. The ring could be forged integrally, but that would complicate the job. When hung, any crane, hoist, or any block and tackle, can be hooked into it and when the load has been lifted clear, it can be run along the track until the desired point is reached.

If this expense is too great, the same results can be obtained by taking a sliding-door track and suspending it from the ceiling beams. Then the two door carriers can be joined by the large end of a V-shaped piece of steel, not less than ½ inch by 2 inches in section; while the carriers are separated and held separated by a simple straight distance piece. The lower end, or point of the V, supports the hook or eye, whichever is used. That is, from an old sliding door, a traveling hoist can be constructed easily and quickly to handle engines or other large and heavy units.

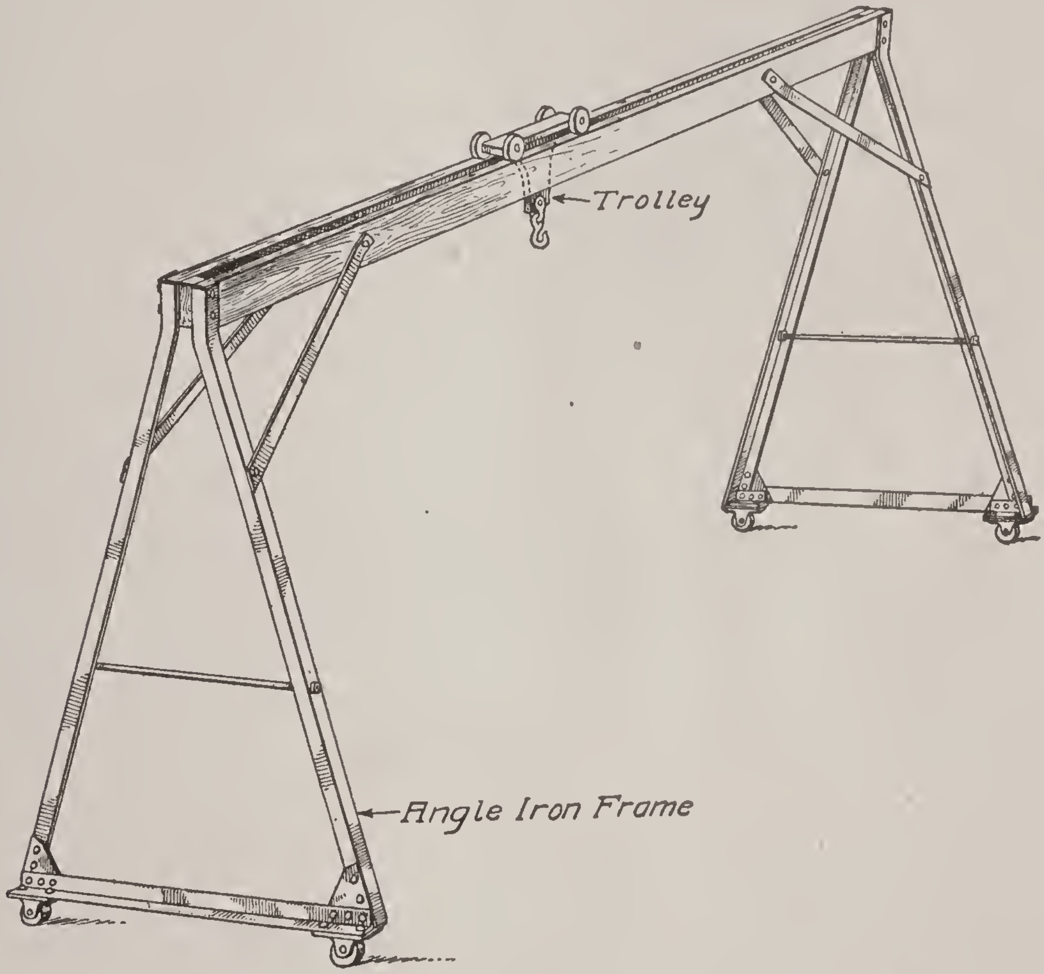


Fig. 8. Overhead Support and Trolley, Used When Roof Trusses Are High or Weak

Floor Type of Hoist Support. When the construction of the roof, or ceiling, is such that it will not permit a suspended hoist, one which works from the floor can be constructed. This consists, as Fig. 8 shows, of a double track beam supported on castor-mounted triangular ends, which extend as high as the garage will allow. By this means, the weight can be lifted clear, and the entire structure moved to the desired place. It is constructed a good deal like those just described; the ends are fair sized angles, say 2 inches by 2 inches by $\frac{3}{16}$ inch; the braces lighter stock, say $1\frac{1}{2}$ inches by $1\frac{1}{2}$ inches by $\frac{3}{16}$ inch; and the castors are anything that is available. It is not necessary that the track be metal; wood can be used if it is wide enough to withstand the wear of the wheels and deep enough to carry the heavy loads.

Commercial Forms. If sufficient money is available to purchase a hoist, these makeshifts are, of course, unnecessary. There are a number of portable cranes for garages on the market, costing from $90 up. These usually have a U-shaped base of heavy cast iron with two castors at the points, and one at the back of the U. At the back also is a vertical pillar about 6 feet high, with a curved extension. At the end of the extension is a grooved pulley carrying a chain hoist. The crane runs back to a sheave and set of gears for winding it up. It has a suitable handle for this, as well as a long folding handle for moving the crane around. Among those available are: the Champion, 550 pounds shipping weight, of $\frac{3}{4}$-ton capacity, with a lift of 4 feet $8\frac{1}{2}$ inches; the Franklin, which will lift 2000 pounds, and weighs 480 pounds; the New Jersey, which will lift 6 feet 8 inches, weighs 600 pounds, and has a capacity of 2000 pounds; the Canton, which will handle 2000 pounds, and lists at $100; the Hilite, which is built in two capacities and four different lifts; and others.

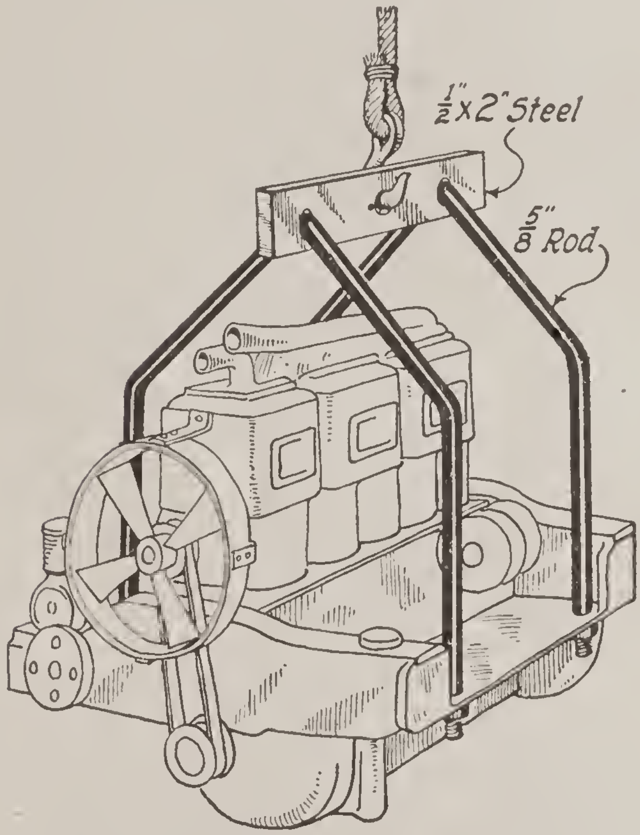


Fig. 9. Sling for Engine Which Saves Much Time in Attaching

Form of Cradle. Many times, even with a suitable crane or hoist, it is necessary to make a cradle for the motor because of difficulty in attaching the chains or ropes to it, difficulty of balancing it safely, or for other reasons. A cradle for a six-cylinder motor is seen in Fig. 9. This is, of course, applicable only to this particular motor, but in a shop handling one car continuously, there is enough saving to warrant making such an outfit. The four bars are made from two pieces of round stock, put through the drilled holes in the upper or supporting bar, then bent over and shaped. Before anything is done, the ends of the bars must be turned down and threaded. In this instance, there is a hole at the four points on the shelf of the motor, so these holes govern the size of the ends of the rods and also their spacing. On almost every motor, there will be some means of attachment which can be studied out in advance, and the rig built to fit it.

Portable Engine Stands. If the engine is removed from the chassis, the first thing needed is a suitable engine stand. One of these is shown in Fig. 10, a form that can be purchased at a reasonable price, and which possesses many excellent features. The frame is made of tubing, which gives a maximum of strength in a minimum of space. The oil drip pan beneath is a good feature, as is the shelf arrangement at the open end. The large castors allow it to be moved around readily and can be clamped to hold it any place. One can be constructed out of heavy galvanized pipe and pipe fittings at a moderate cost.

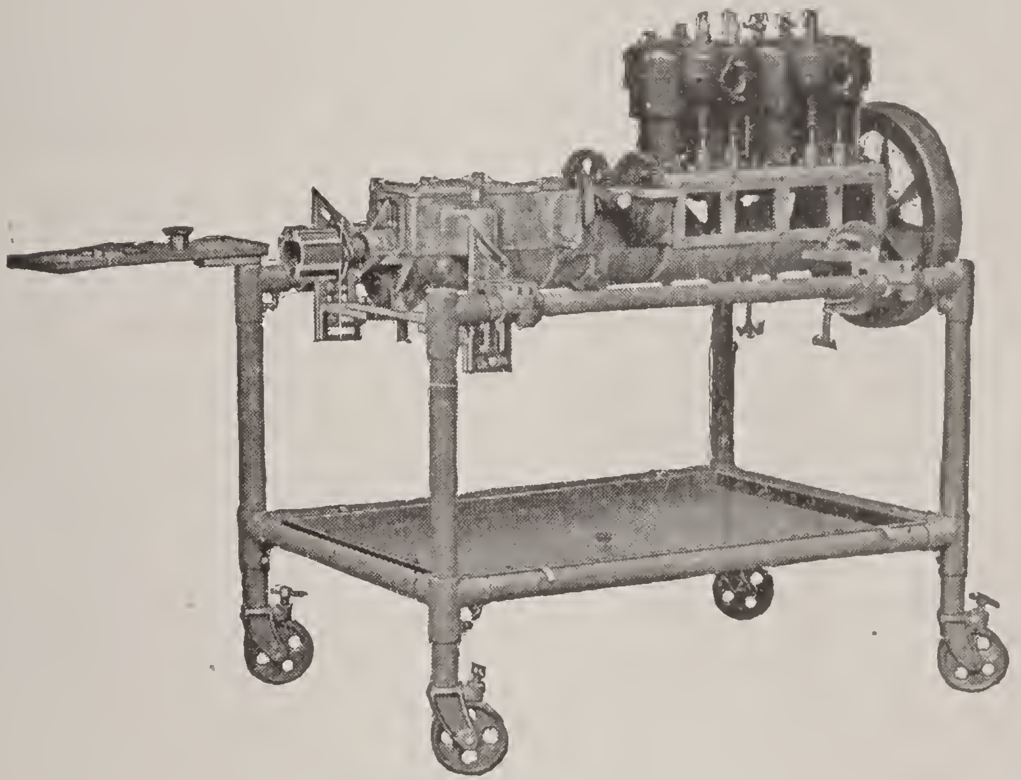


Fig. 10. Handy Form of Engine Stand Constructed from Piping
Courtesy of Shewalter Manufacturing Company, Springfield, Ohio

This form of engine stand holds the motor in its natural, or upright, position. But it is not always desirable to have the engine in that position; in fact, when working on crankshaft bearings and other parts on the under side, it is necessary to have it inverted. There also is work which makes an intermediate position desirable. For this purpose, an engine stand is needed which can be turned to any desired angle and fastened there. Such a stand is shown in Fig. 11, which represents one made by the International Motor Company, Plainfield, New Jersey, for its own use. It would hardly pay to make one of these, as the ends are castings which require a pattern, but if a couple of garages wanting, say two each, would go in together, it would pay to have patterns made for the four. After making castings for their own frames, the garage owners could later make them for sale if they wanted to go into the business. The sketch explains the construction, but this explanation might be added: the central part, projecting from the left-hand member is attached to the rear crankcase arms, and when the engine is turned, this turns with it. The central rotating member on the upper part of the right-hand unit is made to take the starting crankshaft, and the clamp at the upper left is to lock it in the desired position. Eight holes are provided, but a person making one could have as many as he wished, since they are drilled. As will be noted, there are six pieces, but the two bases are made from the same pattern, so five patterns are all that would be needed.

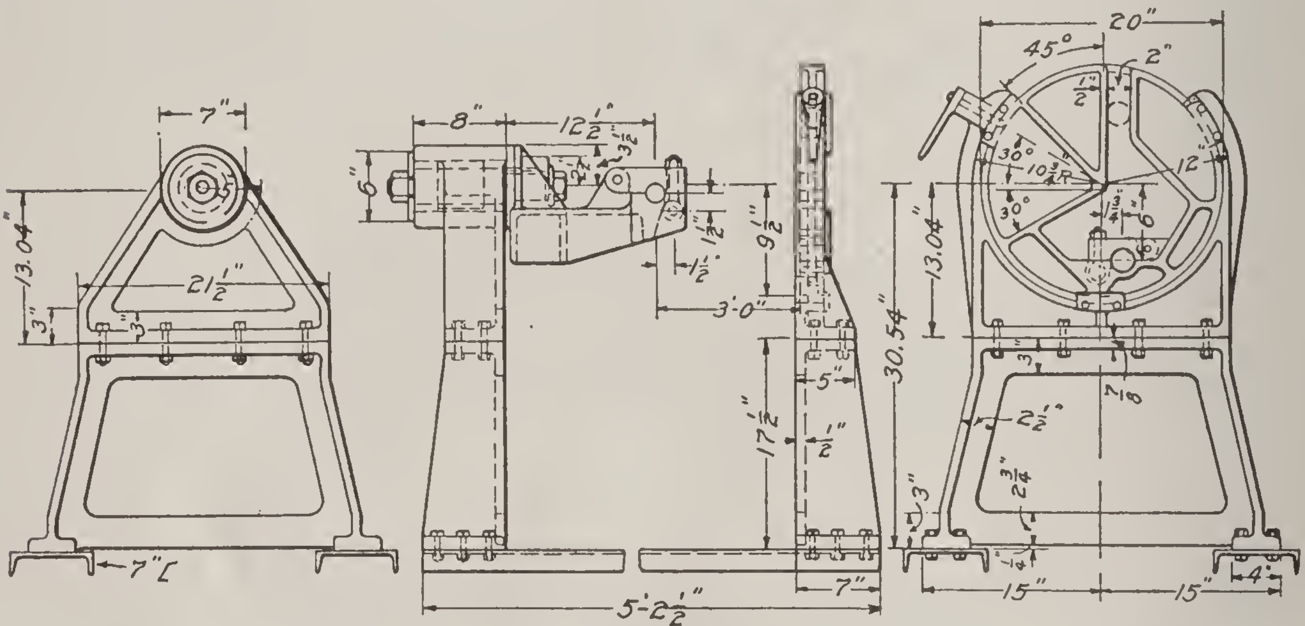


Fig. 11. Engine Stand Which Allows Motor to Be Turned to Various Positions

CYLINDER AND CRANKSHAFT SUB-GROUP

CYLINDER FORMS AND CONSTRUCTION

Materials Used. Gasoline-engine cylinders are variously made of cast iron, cast steel in the form known as semi-steel, forged steel, aluminum alloys, and other materials. For durability, and the ability to withstand high temperatures without warping, nothing has been found superior to cast iron, even though the lightness of steel and of aluminum alloys has commended them for aviation use and in some cases for racing automobiles.

Method of Classifying Cylinder Forms. Cylinders are generally named according to two things: first, the method in which they are cast or produced; and second, the shape of the combustion chamber, or arrangement of the valves. Thus, according to the first method, they are divided into those which are cast separately, that is, each cylinder by itself; cast in pairs, or each two cylinders cast together; cast in threes, a modern modification fitted to the six-cylinder engine; and cast together, or *en bloc,* that is, all of the cylinders cast as a single unit.

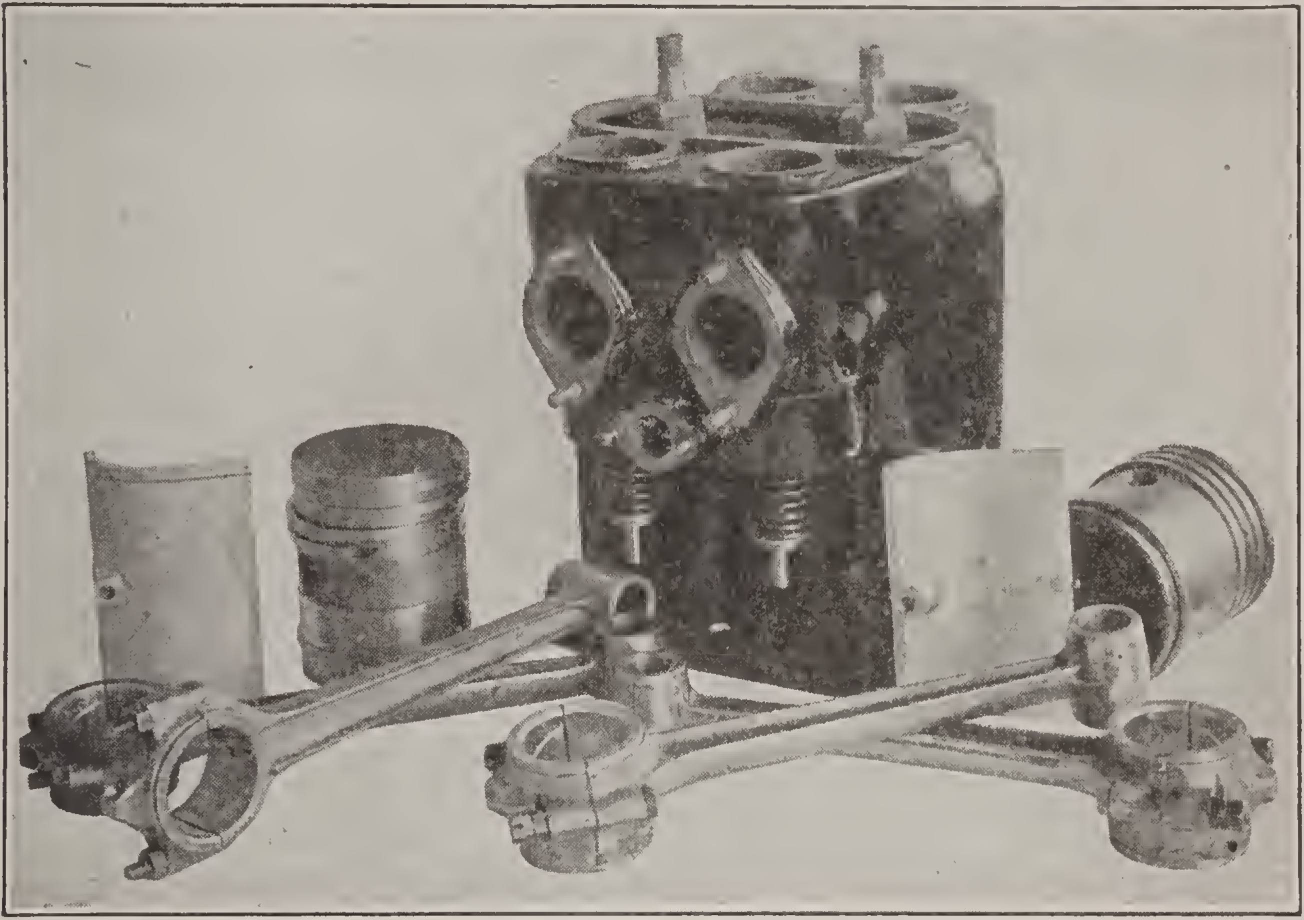


Fig. 12. Typical T-Head Cylinder Units with Other Cylinder Parts
Courtesy of Locomobile Company of America, Bridgeport, Connecticut

According to the second method of naming, cylinders are of the **L**-head type, in which the combustion chamber has the shape of an inverted capital letter **L**, formed by the placing of all valves on one side; of the **T**-head type, with the combustion chamber shaped like a capital **T**, because the valves are equally distributed; of the **I**-type, or valve-in-the-head type, so called because the combustion chamber is left perfectly straight and round by placing the valves in the head; and modifications of these.

Usually in speaking of the cylinders, both names are used as one, as, for instance, those of Figs. 2, 3, and 4, all of which happen to be alike, would be spoken of as **L**-head blocks, Figs. 12 and 13 as **T**-head pairs, etc.

Methods of Casting Cylinders. *Cast Separately.* The early and still common practice in the building of multi-cylinder gasoline motors is the casting of cylinders separately. This policy makes it easier to secure sound castings, simpler to machine and finish them, and less troublesome to disassemble parts of the motor without disturbing the rest.

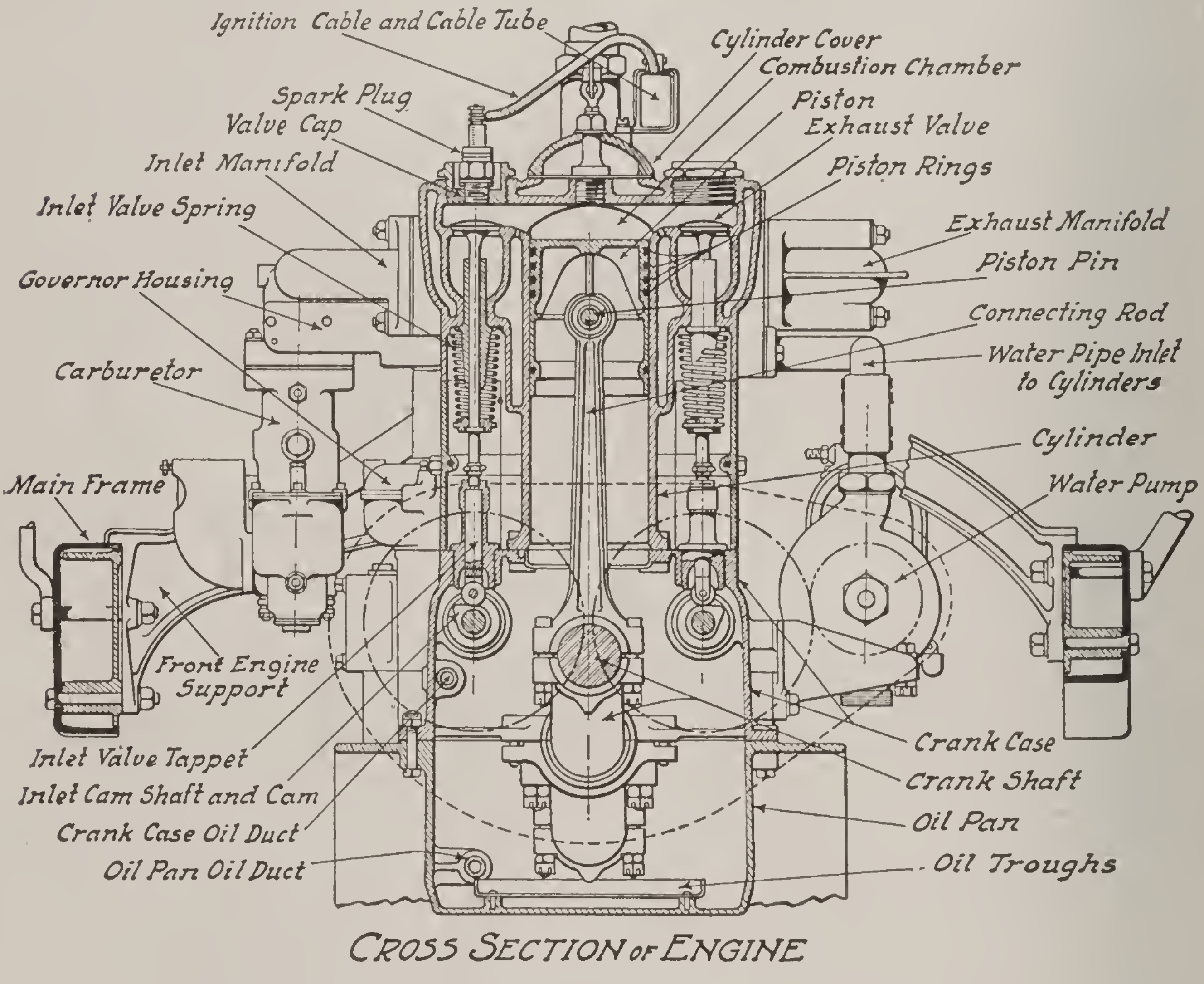


Fig. 13. Section through Locomobile Cylinder Shown in Fig. 12

In a number of cases, where extremely light weight was desired, this method was followed, but the cylinders were machined all over and a sheet-copper water jacket was applied in assembling. This has been most successful in aeroplane work and also for motor cars, but when the Cadillac changed to the form shown in Fig. 3, this construction lost its principal American adherent. In addition to this construction, there have been a number of motors built with an applied water jacket of sheet metal of the built-on form. These have shown splendid cooling abilities, but, under the twisting and racking of automobile frames, particularly in later years, with the use of more flexible frames, they have shown too much tendency toward leakage to become popular.

Cast in Pairs. Just as soon as two-cylinder and four-cylinder engines were produced, the cast-in-pairs form of cylinder appeared and is almost as widely used today as then. While the modern tendency toward smaller bores, compactness, and light weight has greatly increased the number of cylinders cast *en bloc,* the paired form, including the cast-in-threes modification for six-cylinder engines, holds its own.

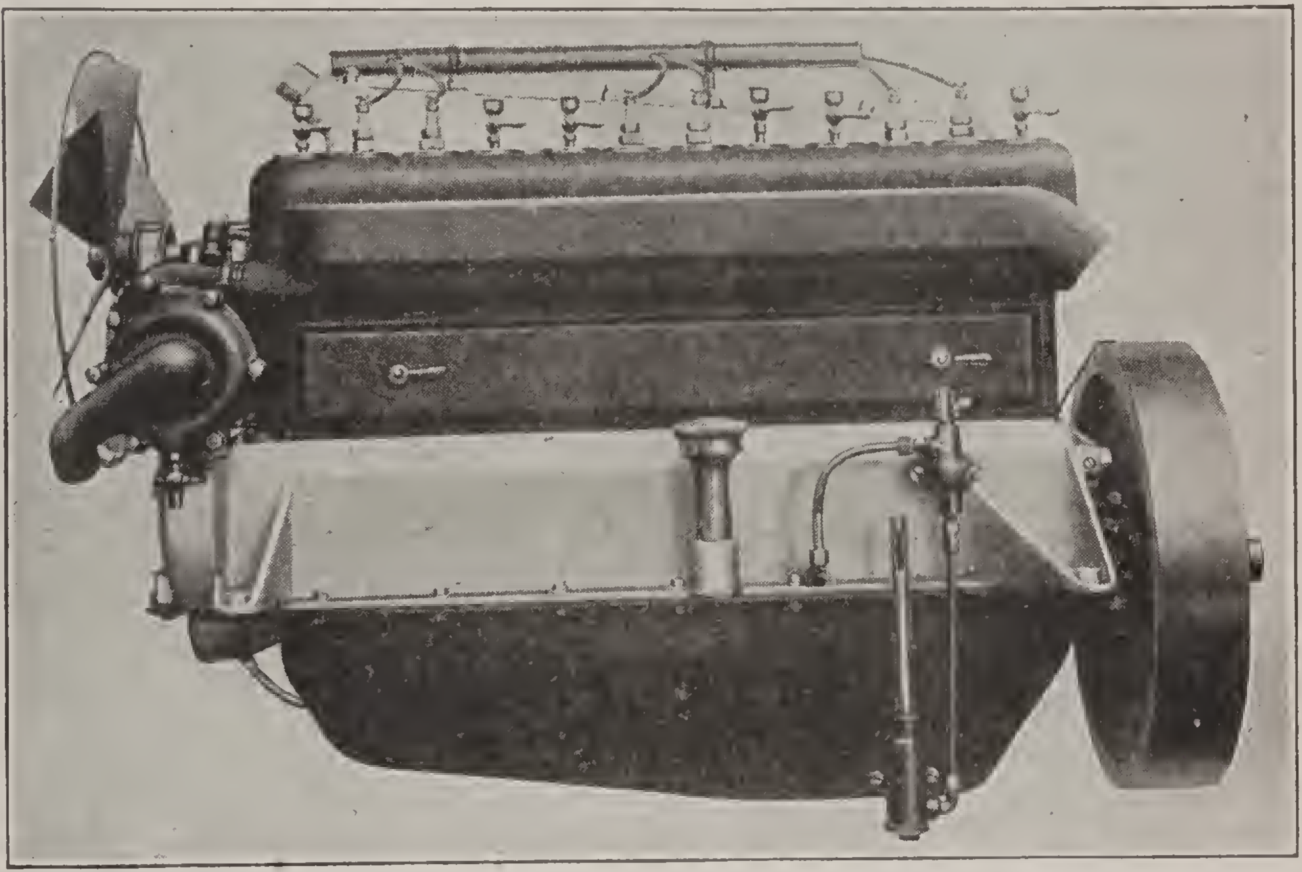


Fig. 14. Studebaker Six-Cylinder Motor, Showing Block Castings of the Six Cylinders

Cast Together. The great advantage of having the several cylinders of one motor cast together—*en bloc,* as the French term it—is that the alignment and spacing of the different cylinders is thus rendered absolute and permanent, regardless of any differences in adjustment that may otherwise occur in assembling.

This construction has been applied to a large proportion of the small and of the medium-sized fours, a fair proportion of the larger fours, and to a considerable number of sixes, Fig. 14.

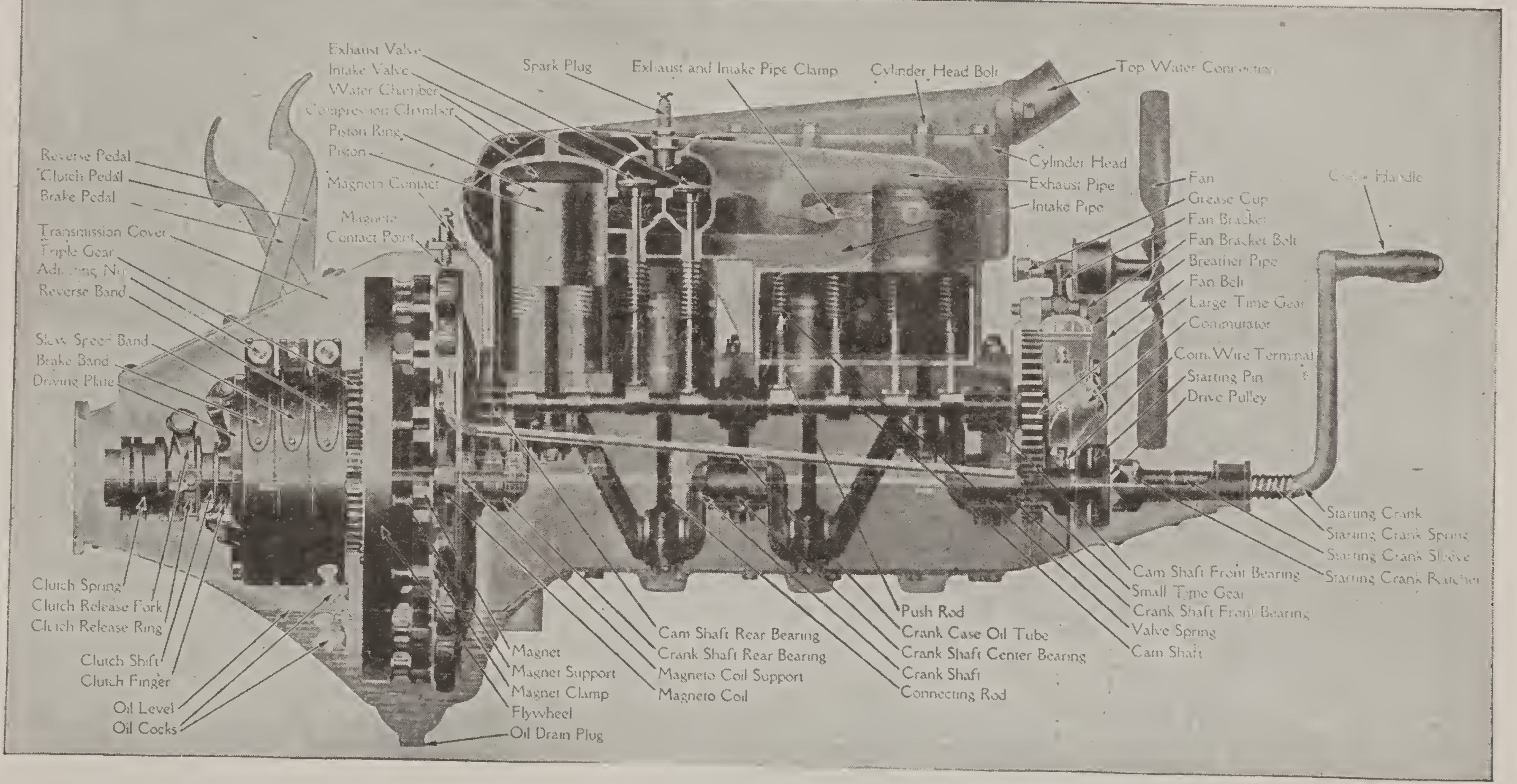


Fig. 15. Part Section of Ford Motor
In this engine cylinders are cast together

Another advantage is, that the water connections, exhaust and intake manifolds, etc., are rendered simpler both in their form and the number of their points of attachment.

In some advanced motor designs, the passages for the incoming mixture and for the exhaust gases, and in one case even the carburetor itself, are all incorporated in the main casting.

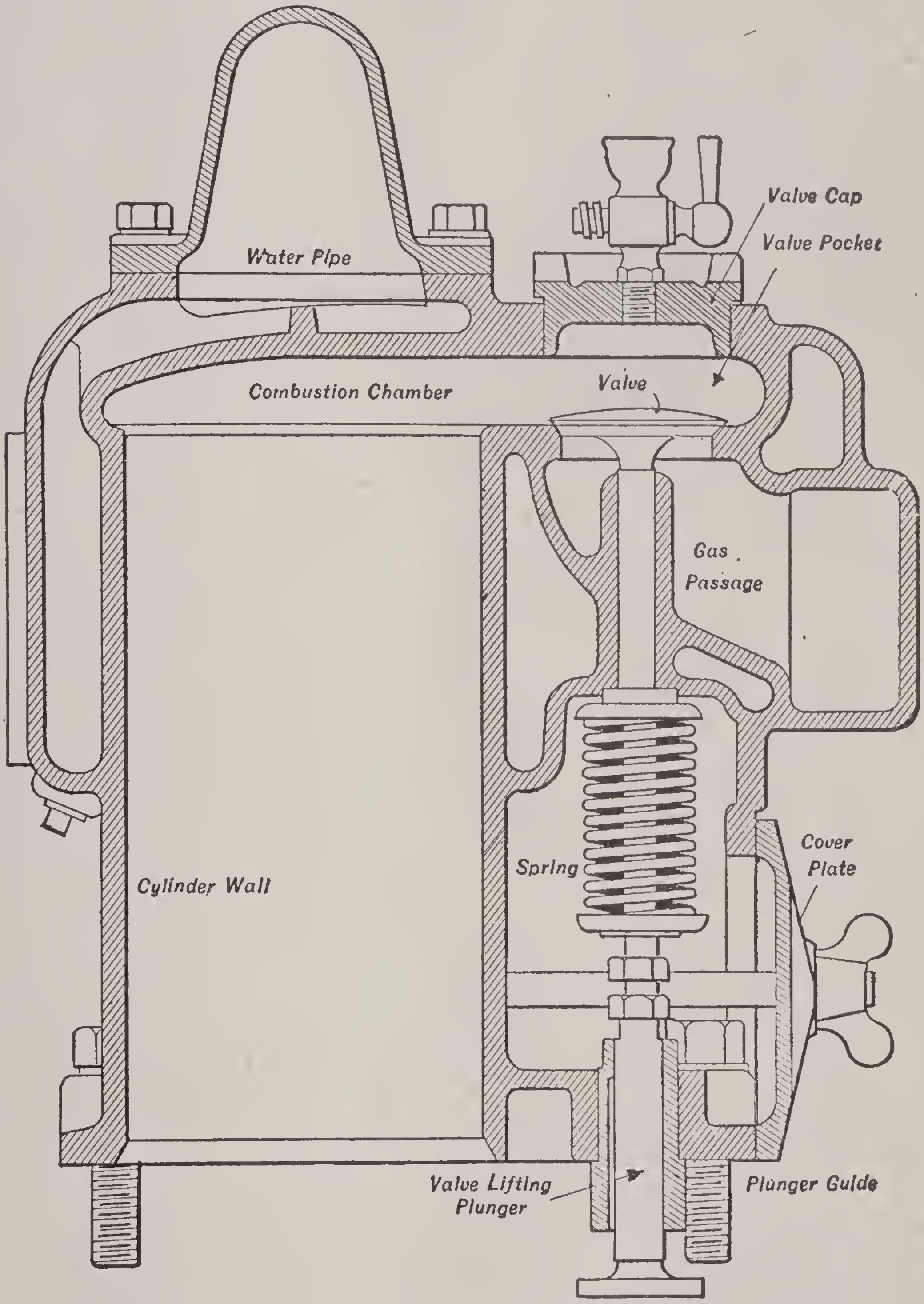


Fig. 16. Section through Typical L-Head Cylinder with Valve Parts in Place

Courtesy of the Hudson Motor Car Company, Detroit, Michigan

Another example of simple construction is that illustrated in Fig. 15, which depicts one of the latest Ford motors, in which cylinders, upper half of the crankcase, and the gearbox are all cast in one piece. The lower half of the crankcase and gearbox are similarly constituted of another simple pressed steel unit, while a second casting is used for the heads of the cylinders and for the water connection.

Cylinders Classified as to Fuel Chamber or Valves. **L**-*Head Forms.* In the **L**-head form, the valves are all located on one side, and usually because of this, all the accessories are on the same side. This makes a lop-sided engine, with carburetor, inlet pipe or manifold, magneto and wiring, exhaust manifold, and sometimes electric generator and other parts all grouped on one side, with little or nothing on the other. While a disadvantage in four- and six-cylinder motors, this is somewhat of an advantage in eight- and twelve-cylinder forms, for all the parts and auxiliaries can be grouped in the V between the cylinders, leaving the outside clear. On the other hand, where this grouping has been found undesirable for four- and six-cylinder motors, it has been possible to overcome it in part by taking the magneto and carburetor over on the other, or plain side, of the cylinders, leading a conduit back for the wires in the one case, and a long inlet manifold in the other. An **L**-head cylinder is shown in Fig. 16.

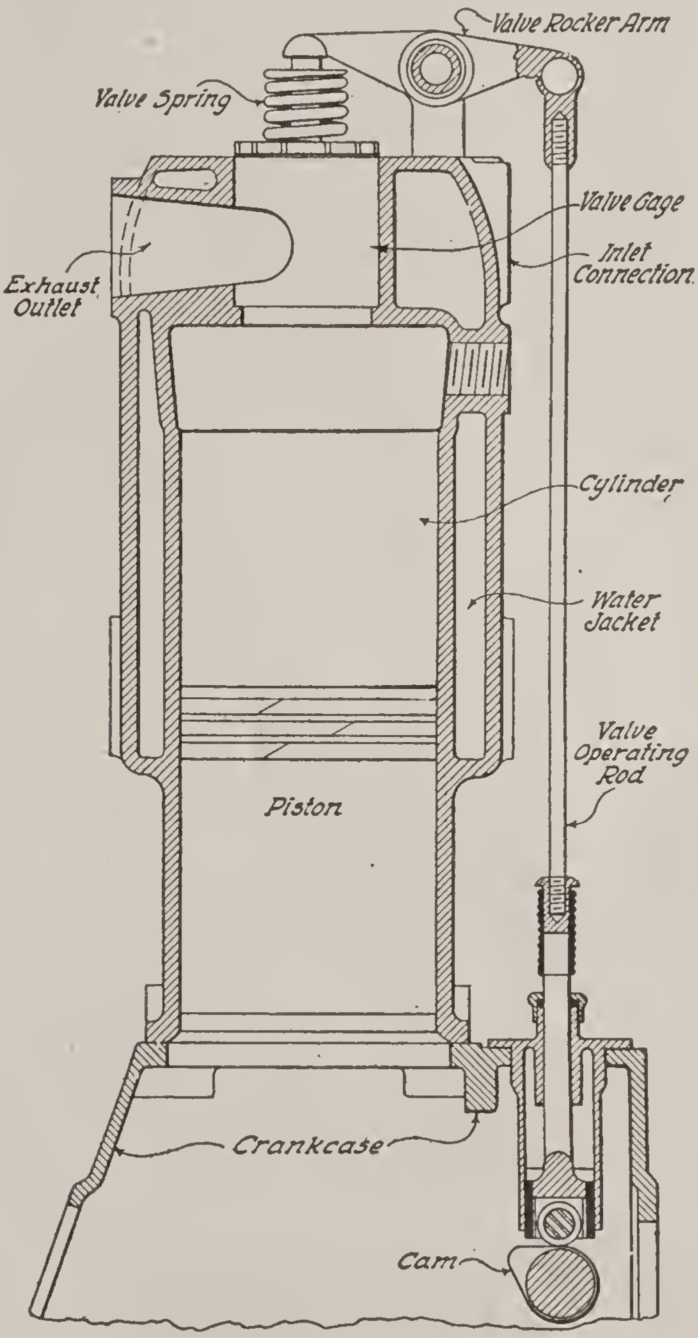


Fig. 17. Section through Dorris I-Head Cylinder as Used with Valve-in-Head Motors

T-*Head Forms.* A desire for more symmetry and a better arrangement has brought about the **T**-head form, which has the inlet valves, carburetor, and inlet manifold on one side, and the exhaust valves and manifold on the other. This separation gives more space on both sides, and allows the distribution of the other engine accessories so that each has more accessibility. This is important, for some parts, like the magneto, do

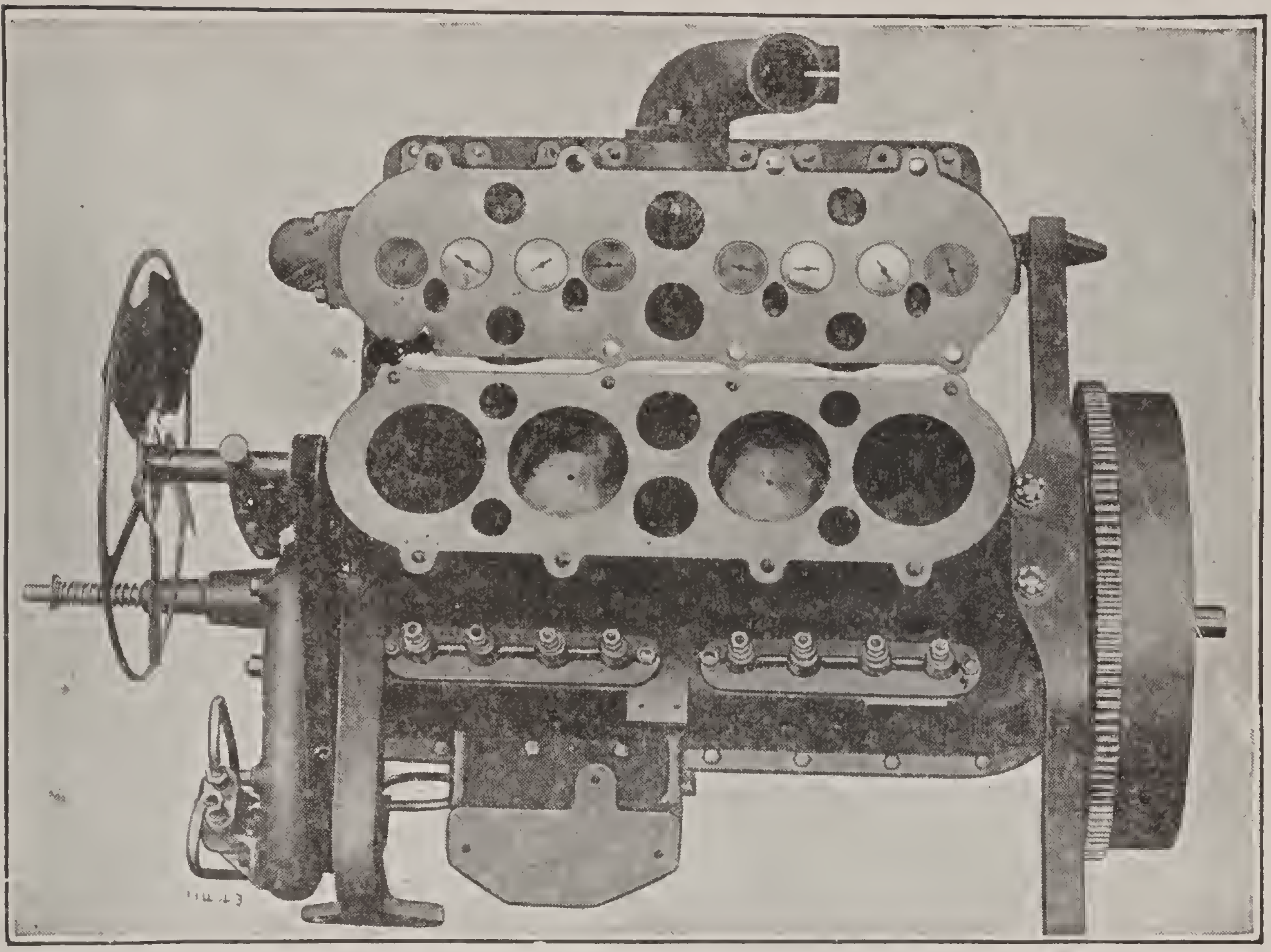


Fig. 18. Typical Arrangement of Overhead Valves of Interstate Motor

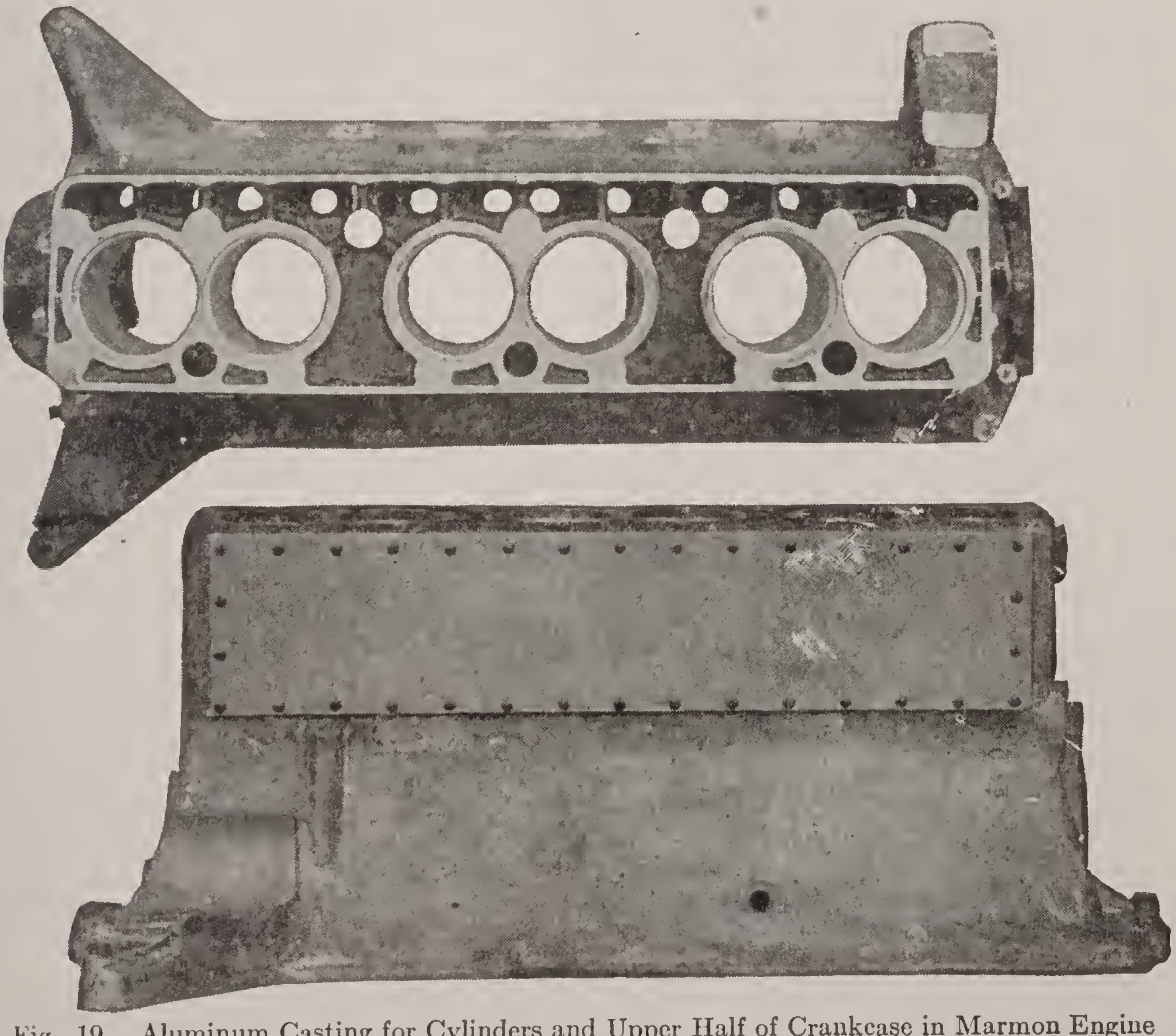


Fig. 19. Aluminum Casting for Cylinders and Upper Half of Crankcase in Marmon Engine

not withstand the heat well, and consequently should be far away from the heat of the exhaust manifold. See Figs. 12 and 13.

I-Head Forms. The valve-in-the-head, or overhead valve, motor requires an I-head cylinder, because, with this location of the valves, there is no necessity for the valve pockets of the other forms. Consequently the cylinder can be straight and plain, while the head, which is separate, is fastened on instead of being cast integrally. It may have either the L- or T-form, according to the location of the valves and the inlet and exhaust manifolds. Fig. 17 shows an I-head in which the manifolds are located on the opposite side. Note that in this form the cylinder head is integral, the valves being set in cages which are removable, as shown in the view of the Interstate Motor, Fig. 18.

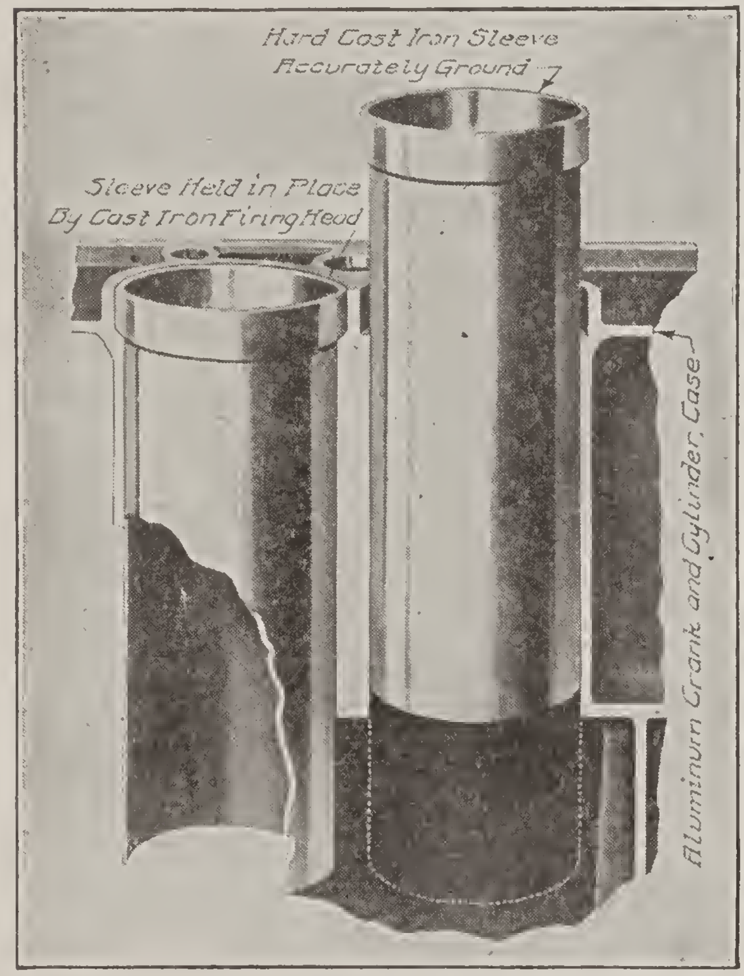


Fig. 20. Detail of Marmon Cylinders Showing Cast-iron Sleeves Inserted in Aluminum Casting

The forms are not so clearly separated as they were formerly, for the inclusion of cylinder heads in one case, and their exclusion in another; the integral casting of manifolds, water passages, etc.; the casting of crankcase upper halves and also of gear covers, flywheel enclosures, transmission cases and other parts, all of which are quite common; no longer leave the cylinder casting as a single simple clear-cut unit.

A marked example of this is seen in Fig. 19, in which the six cylinders, with water jackets and water passages, and the upper half of the crankcase are cast as one. The detail of this, shown in Fig. 20, indicates the cast-iron sleeve, inserted to form the long-wearing cylinder bore within the aluminum structure, which is easier to cast in this complicated form. To a certain extent this modifies what was previously said on the subject of materials, for in this case the material of the cylinder is not of one but of two kinds, cast iron and aluminum.

Cylinder Repairs

Removal of Carbon. One of the things every repair man must do is remove carbon. A good method is the introduction of a metal object, as a ball or a piece of chain, which the piston is allowed to bounce up and down to break up the carbon. This is successful, but there is always the danger of the part getting under a valve or other part, and causing trouble.

A better way is to couple up a number of short lengths of chain—old tire chains will do—and attach them to the flexible shaft of a buffing or polishing outfit, as shown in Fig. 21. This chain and shaft end can then be introduced into the combustion chamber and, when the current is turned on, the rotation breaks off all carbon.

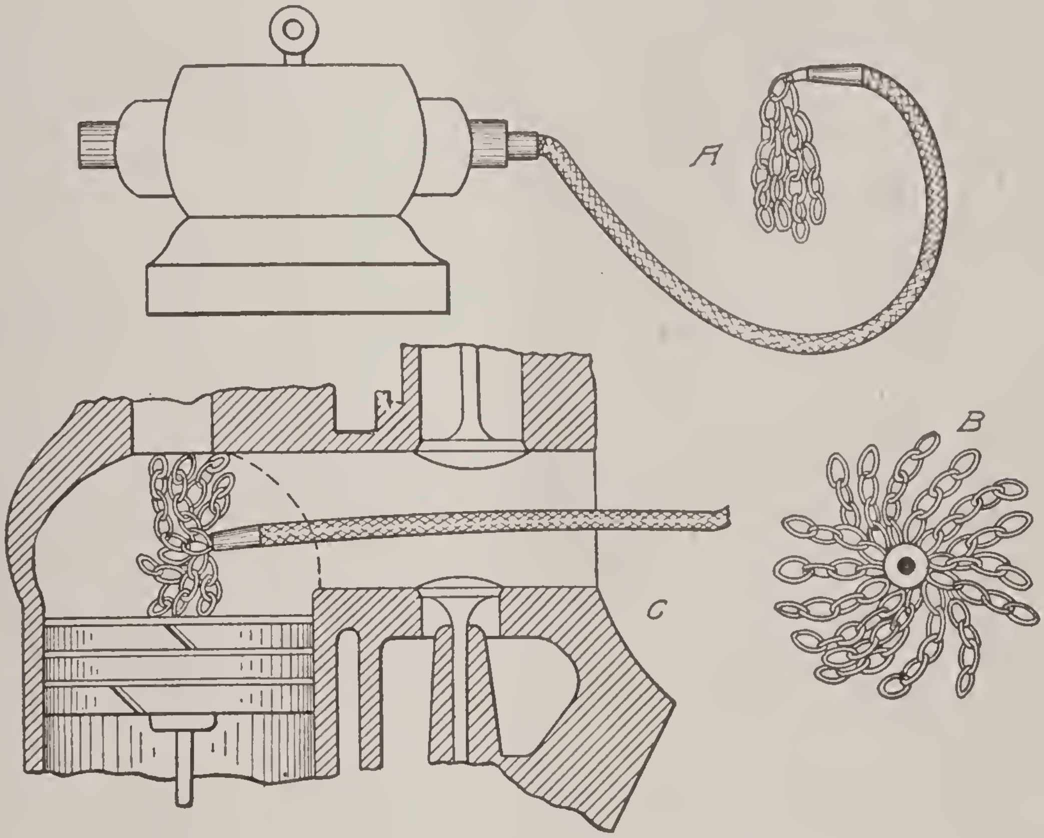


Fig. 21. Removing Carbon with Flexible Shaft and Old Chain (*A*) Motor, Shaft, and Chain; (*B*) Method of Assembling Chain; (*C*) Device in Use

Carbon on Fixed Cylinder Heads. When the motor has fixed cylinder heads, and the valve opening is small, this is not always a good way. Another somewhat similar tool can be constructed to go in through the bore of the cylinder and clean off the cylinder head very nicely. This is shown in Fig. 22, at work (at right) and in detail (at left). It consists of a round steel brush with very stiff wire bristles mounted in a four-cornered frame. The latter should be smaller than the cylinder bore by $\frac{1}{4}$ inch or so, but the bristle circle should be full diameter. When rotated by means of a flexible shaft, the outside bristles have a tendency to throw outward, so that this device will clean a space considerably larger than its diameter when at rest.

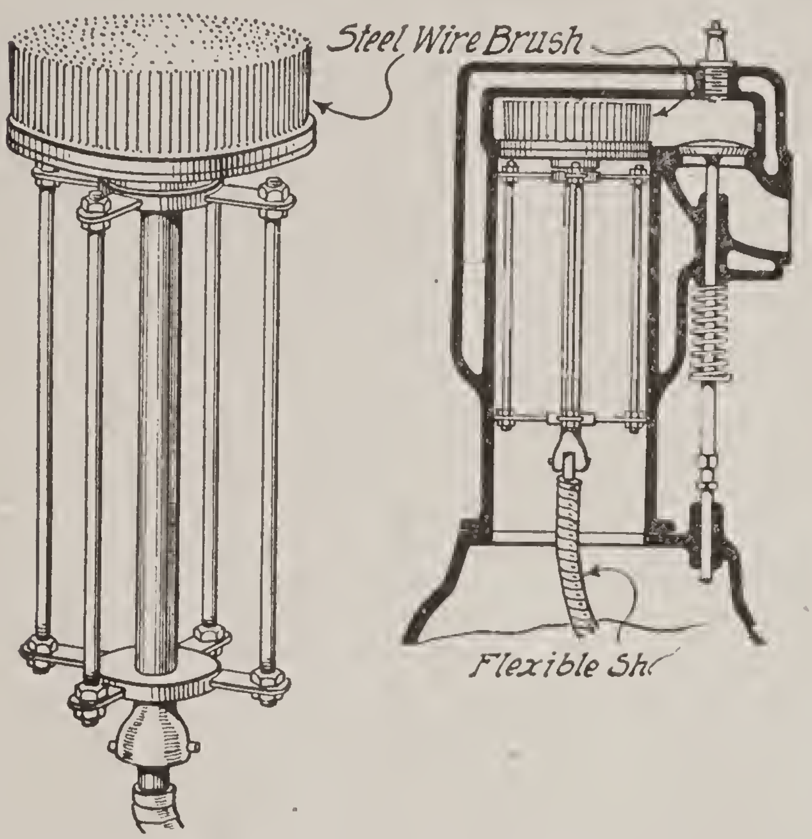


Fig. 22. Steel Wire Brush and Flexible Shaft Method of Removing Carbon from Cylinder Heads

When the electric motor, or electricity to furnish power for the device shown in Fig. 21 is not available, similar results can be obtained by attaching a geared hand drill, as shown in Fig. 23. When this is used, however, it is difficult to attain sufficient speed to expand the chain, so a wire brush with fairly long wires will be found better suited. Several sizes of

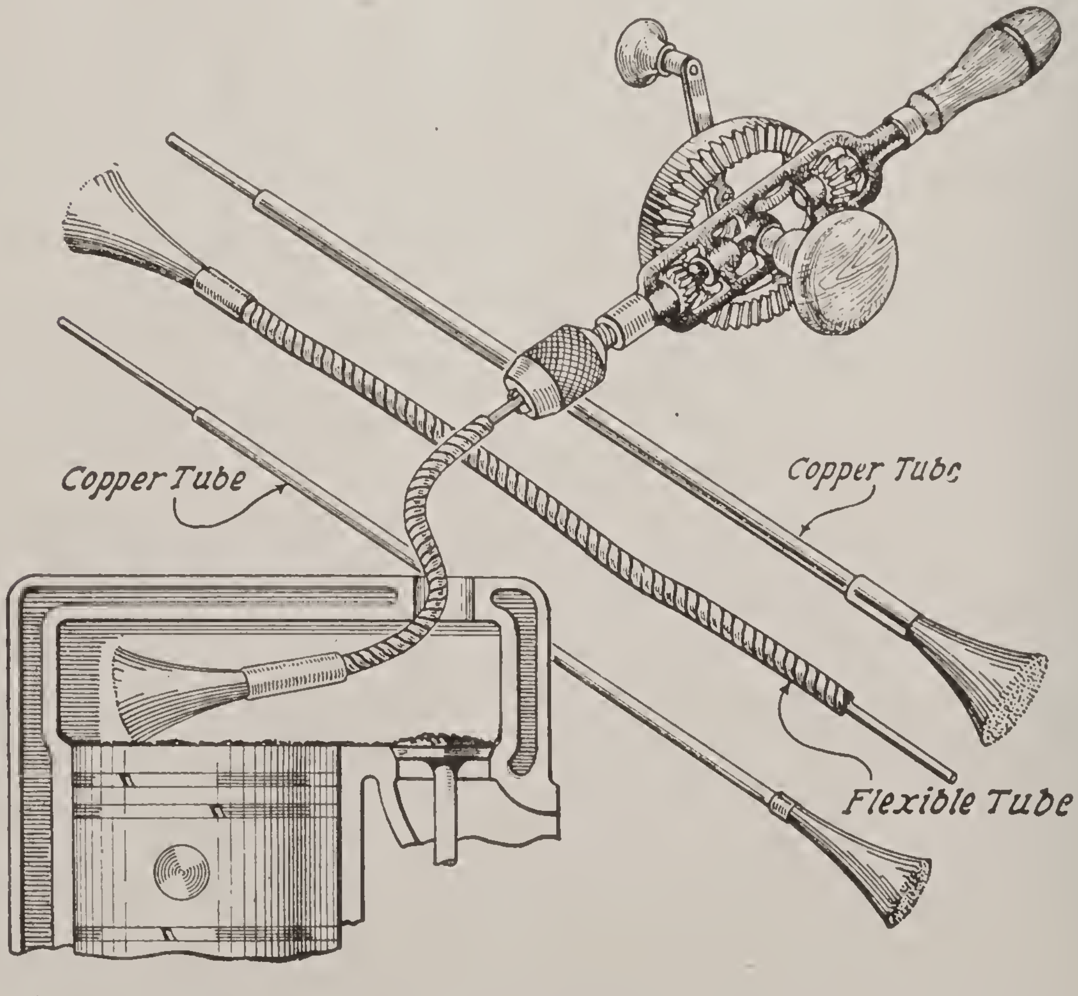


Fig. 23. Removing Carbon from Cylinder Head with Brace and Wire Brush

wire—long, short, and medium—will come in handy, also brush ends with various diameters of shank, with copper tubing around the actual shaft, or flexible tubing. This can be inserted more readily than the chain "mop" shown in Fig. 21. But, as stated above, it cannot do equal work, because it cannot be revolved so fast.

Compressed Air. If the cleaning periods for the engine are not too far apart, the greater portion of the carbon can be blown out with compressed air by using the air after a chain "mop" or wire brush just described. To use the air, however, calls for a special fitting, two of which are shown in Fig. 24. The one at the right is the most simple, but the one at the left has the advantage of being made from pipe fittings instead of from brass tubing. Both screw into the opening in the center of the cylinder head, and the air enters through the central hole, while the carbon is blown out through the larger annular opening.

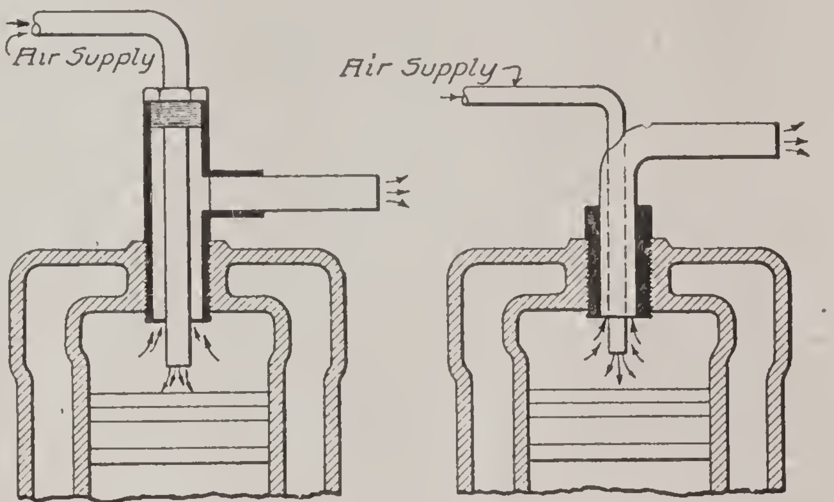


Fig. 24. Set-Up for Blowing Out Carbon from Cylinder Heads after Loosening

Liquid Solvent. Nowadays, carbon removal is often accomplished by means of liquid solvents. Of these, kerosene, denatured alcohol, and special preparations are the most widely known and used. Kerosene is used when returning from a trip. Just before stopping the engine, it is speeded up and a little kerosene inserted into each cylinder. This loosens the carbon so that it blows out through the exhaust.

Denatured alcohol and also the special preparations are used in much the same way, except that the engine is not run. After returning to the garage, and while they are still hot, an ounce or so is placed in each cylinder and allowed to stand there over night. On starting the motor the next morning, the loosened carbon is blown out through the exhaust pipe. If the carbon is very thick, more alcohol must be used and allowed to stand for a longer time. By repetition, this will gradually clean out all there is in the cylinders.

Removing Carbon by Scraping Tools. When all other means of removing the carbon fail, the repair man must go back to hand scrapers. In any case, these are the most simple and fully as effective as any; provided the extra time needed to use them and do a good job is available. When the offending member has been brought out so it can be handled, the removal of the carbon can be accomplished in a few minutes. A flat piston head, like that shown in Fig. 25, can be scraped off with any knife or chisel, but a special scraper made from an old file, flattened out at the end, and ground down so as to present one sharp edge is better. Every garage man should accumulate from five to a dozen shapes and sizes of scrapers for various work, including a flexible one with which to reach into corners. The carbon is brittle and comes off readily. After its removal the surface should be filed or rubbed over with emery and oil to make it smooth, in order to delay the formation of a second coat. This is true of carbon in other places, but usually it is impossible to smooth the surface, in which case the process must stop when the part is scraped clean.

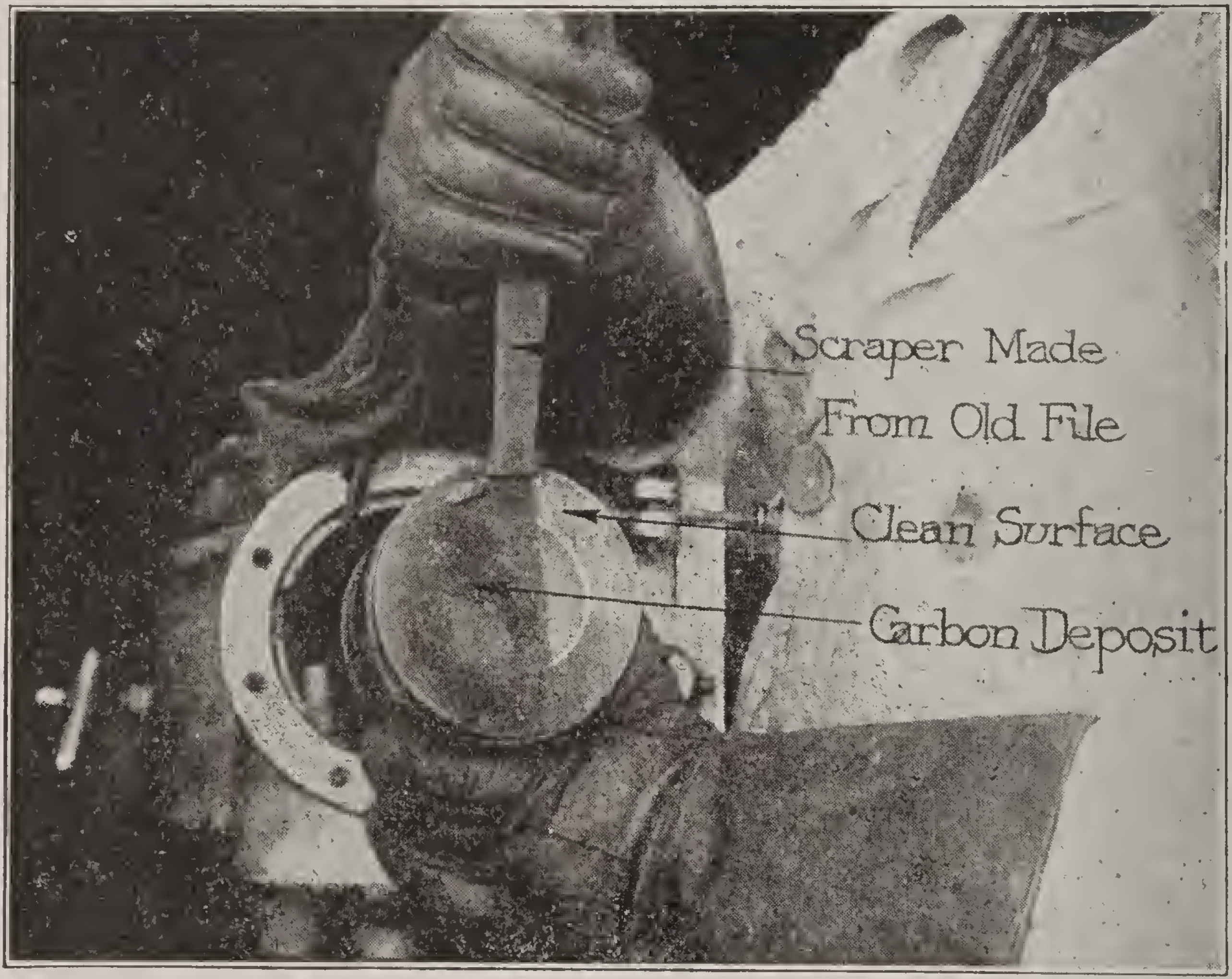


Fig. 25. Removing Carbon with File

A number of excellent plain and special forms of scrapers which the average garage should have are illustrated in Fig. 26. The one at the top, *A*, is a plain straight scraper with a hooked end. Where there is plenty of room to work, this is the usual tool. That at *B* is somewhat similar, except that the length is greater, and the end is bent. This allows of getting up or down further than with the straight tool. A form with a double bend, no handle, and a scraper at each end is shown at *C*. The advantage of this lies in getting around curves and corners. Still another at *D* has the same curves and a similar double curve in the other direction; this also allows working into deep corners. That indicated at *E*, with a shape like a hoe, is made that way to conform to the upper curved surface of the ordinary combustion chamber and the flat top of the piston. The handle screws in, and to insert the tool in the motor, it is taken apart, and parts put in through separate holes and assembled or screwed together inside. The form at *F* is particularly suitable to the eight-cylinder Cadillac cylinder head, but may be used with any motor having a similar design. It is a rotary form, the central plug being screwed in, to replace the cylinder-head plug. The rotation of the handle outside causes the tool inside to turn

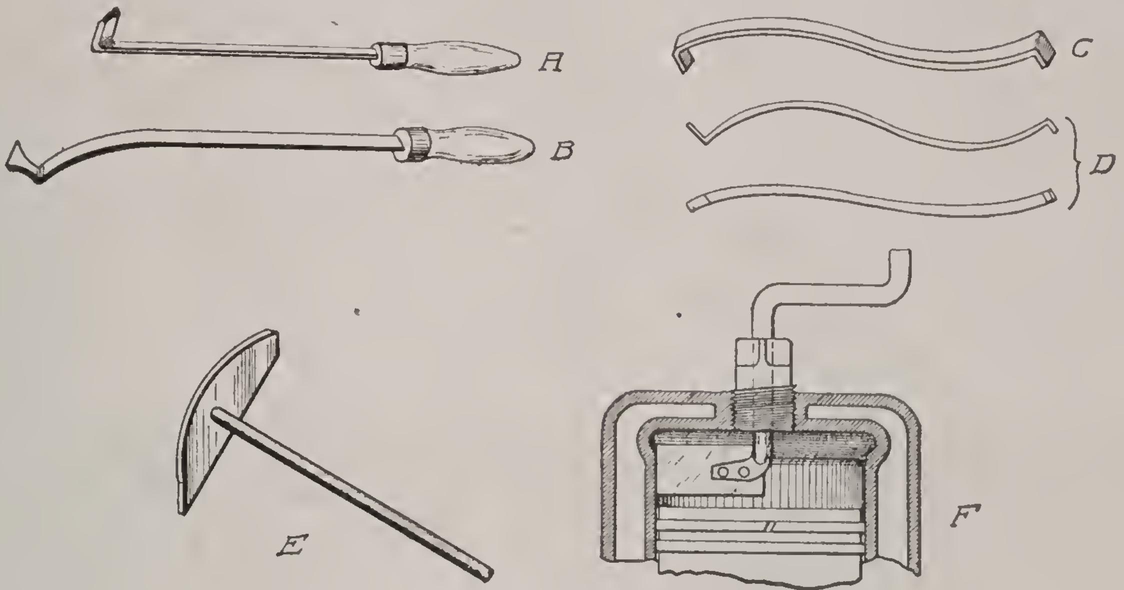


Fig. 26. Various Types of Carbon Scrapers

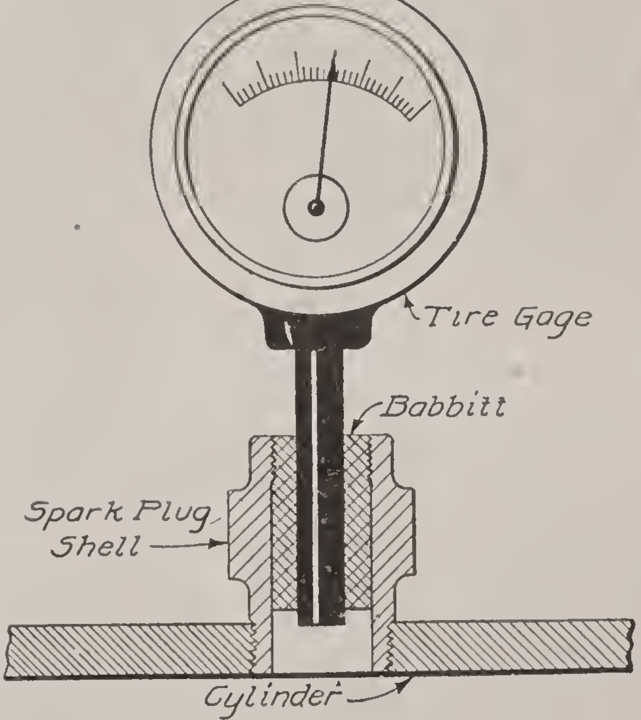


Fig. 27. Compression Gage for Testing Cylinders Made from Tire Gage and Spark Plug Shell

around over the surface of piston top and combustion chamber. When used against the top it is pulled upward. It is pressed down when used against the bottom, or the piston. Other special forms will be constructed by the clever workman for certain motors having peculiarities which make these specials desirable and time-saving.

Compression Indicating Gage. Before taking off the cylinder to look for trouble inside, the repair man should do all he can to find out what and where the trouble is. A compression gage is handy, as this indicates the pressure in each cylinder. These should all agree when the motor is right, but if pistons or rings are not right, or if the cylinder is scored, the gage will show a lower figure than the other cylinders. Such gages can be purchased or can be made from old materials on hand; as, for instance, that shown in Fig. 27, which was made from an old spark-plug shell and a tire gage. The stem of the latter was set inside the shell and firmly fixed there by means of babbitt after both were scored so the metal would take a firm hold. Whenever a motor acts peculiarly, the spark plug is removed from each cylinder in turn, the home-made gage inserted, and the reading noted (with the motor running or being turned over by hand). Many times leaky valve pistons or valve-stem guides will cause a miss

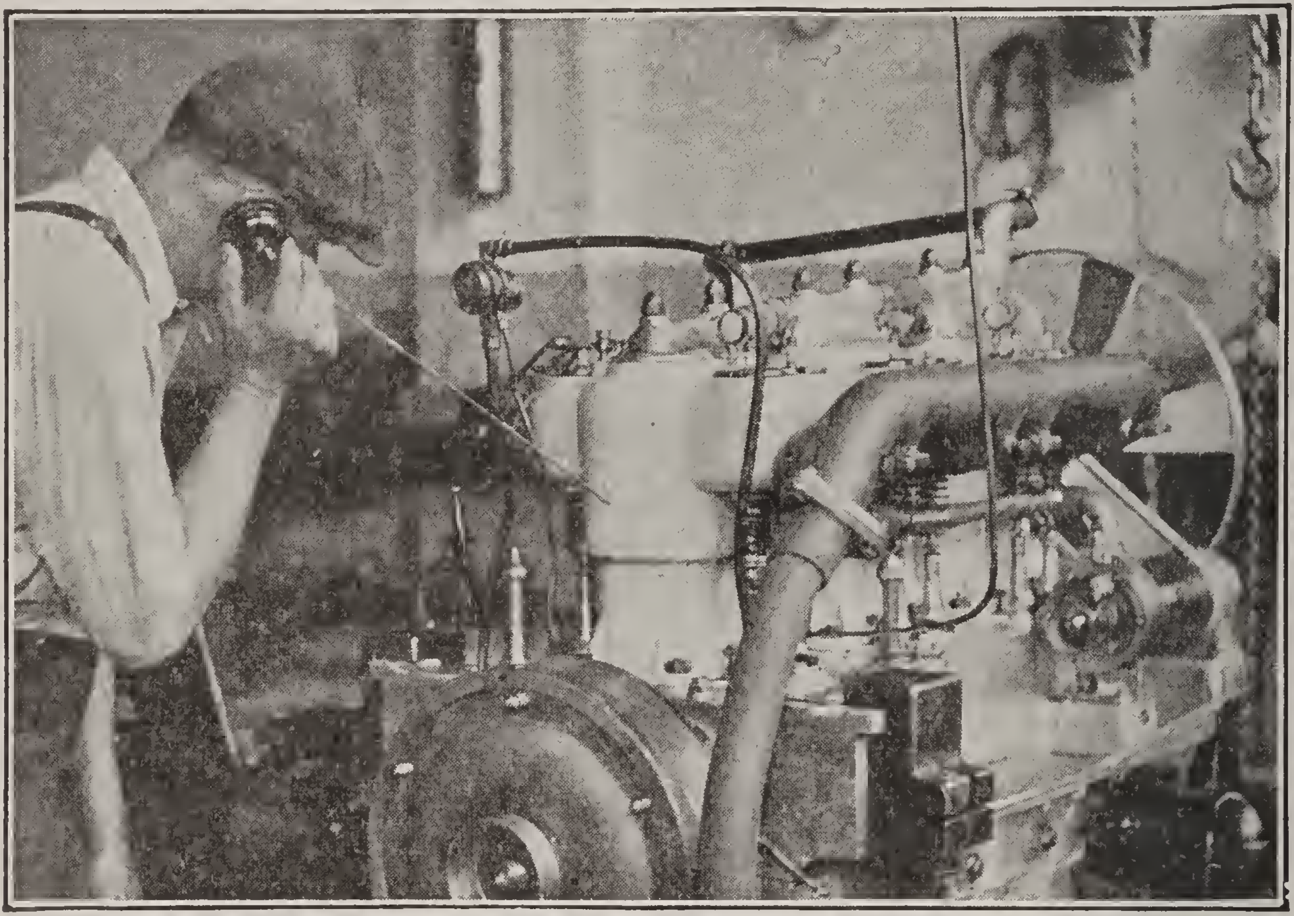


Fig. 28. Using Stethoscope to Listen to Engine Noises

which nine persons out of ten would blame to the carburetor. This gage will show up these leaks.

Locating Noises by Means of a Stethoscope. Besides this, it should be borne in mind that there are many sources of noise in and on the engine other than that produced by valves and valve motions. In fact, the noises made by the valves, while an indication of loss of power, do not represent anything like the possibilities for trouble indicated by a piston slap, a crankshaft or connecting-rod pound, the whirr of worn timing gears, and others. In order to locate such sources of noise exactly, at a time when the beginner lacks familiarity with the motor and its troubles he should purchase or borrow and learn to use a stethoscope, Fig. 28. A modification of the surgeon's well-known instrument is now made for use in automobile trouble finding.

The stethoscope, or its modification, simply magnifies all noise; its construction is such that one end is held against the suspected part, while the other end constitutes an ear piece. When the engine begins to make a great deal of noise, particularly heavy pounding noises, this should be brought into play. With the motor running, place the free end against the various parts of the engine, going slowly from one to another. In this way it will soon be found where the trouble lies.

A piston slap is not so easy to define or so easy to repair. It may be called a noise which comes from within the cylinders, traceable to the pistons, or to one piston, as the case may be, which sounds very much like a shaft pound, except that it is a louder noise. It occurs when pressure is put on the piston, as at the beginning of compression, at the time of explosion, or at times at the end of each stroke. It is said to be due to different causes. Some say it is caused by a loose piston pin, but the writer knows of two cases in which a new tight pin left the piston slap just as clear and distinct as before. Others say it is caused by rings which are loose up and down in their grooves, but in the cases above, new rings which fitted tightly in this way did not help any. It has been ascribed to a piston which was out of round, so that it did not fit the cylinder, and also to a groove and shoulder having been worn in the cylinder surface, the piston striking this each time. Whatever is the real cause, and the writer is inclined to blame it to a poorly fitting piston, nothing will really remedy it but a new piston, complete with rings.

Making Gaskets. Anyone who is going to do much repair work will soon have to learn the art of making gaskets, for, in almost every case, the removal of a paper gasket is accompanied by its breakage, so it is rendered unfit for further use. A gasket, it might be explained, is a formed sheet of heavy paper, cardboard, or special material fitted between two surfaces of a joint which must resist the leakage of gases or liquids under pressure. By means of the bolts or screw threads which hold the two parts of the joint together, the gasket is compressed and, in its compressed state, it resists the internal pressure.

The following method of making gaskets applies alike to round, oval, and odd-shaped ones, which cannot be said of special tools and fittings for gasket cutting: Select a good piece of heavy brown wrapping paper or special gasket paper without too many wrinkles, and free from cracks or flaws. Clamp the part for which the gasket is to be made in a vise to steady it and lay the paper over it. Then go around the edges of the part, tapping lightly on the paper with the flat face of a hammer, holding the paper in position meanwhile with the other hand.

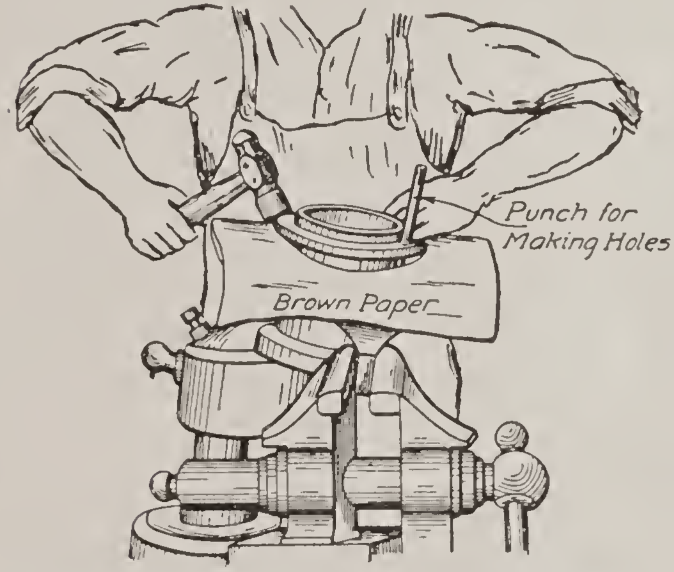


Fig. 29. Cutting Gaskets on the Parts with a Hammer Is the Best and Quickest Method

This method is illustrated in Fig. 29, where a workman is shown making a gasket for the base of a cylinder. In this particular instance, holes must be made through the gasket for the cylinder bolts. These are made with the round or peen end of the hammer or with the punch. When made, the punch is stuck into the hole to help hold the paper steady. In this case, too, it was necessary to cut the inside of the gasket out first, then this material (the paper from the inner or smaller hole) was removed, the sheet put back in place on the base of the cylinder, and work started on the exterior cutting.

If the hammer be held at a sharp angle with the edge of the part for which the gasket is being cut, each blow will cut through, or partly through, the paper. By repeating this operation enough times, going around the part meanwhile, the result is the finished gasket which will fit the desired place exactly.

Cylinder Heads. A great many motors have detachable heads, and their quick removal is a great convenience, when there is carbon to be scraped off, pistons to be looked over, or other internal work to be done. However, replacing them is never quite so easy as removing them, partly on account of the cylinder heads themselves and partly on account of the pistons. The latter are particularly troublesome when the cylinder head is hinged. The cylinder head should be replaced with great care, and after replacement it is fully as important to bolt it on properly. If one bolt or a series of bolts is tightened too quickly and too hard, it is likely to result in cracking the cylinder casting or the head casting or both.

Proper Method of Bolting on Head. Usually, on an **L**-head type of motor, there are three rows of bolts for the cylinder head—one row along the middle, screwing into one side of the cylinders; another row screwing into the other side of the cylinders; and a third along the valve side. These should be tightened in order: first the middle bolts of the middle line, working out to the ends; next in turn, the middle bolts of the back of the cylinder, the middle bolts of the valve side, the ends of the cylinder; and finally, the end bolts on the valve side. All these should be tightened but a few turns at a time, and after all are down, a second round should be made in about the same order, to give each bolt a few more turns. In this way the cylinder head casting, which is both large and intricate, is slowly pulled down to the cylinder straight and true so that it is not warped or twisted. Moreover, if the cylinder is pulled down straight in this manner, all the bolts can be tightened more than if the first bolt were tightened very much, for the latter would result in cocking up the opposite side.

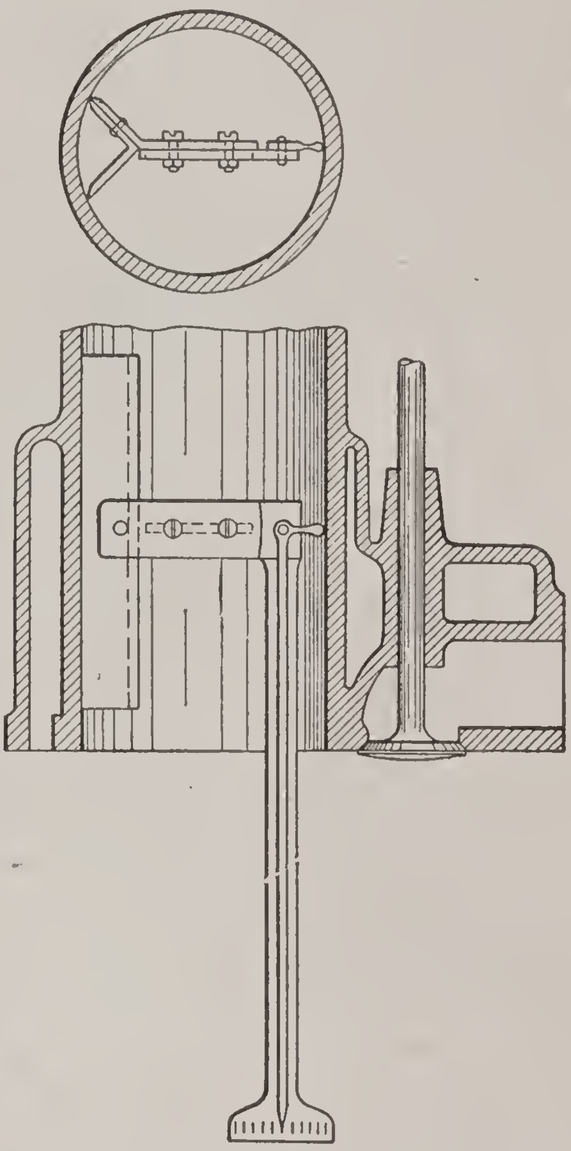


Fig. 30. Construction of Simple Rig for Measuring Worn Cylinder Bores

Checking Up Cylinder Bore. Before any work is done upon the cylinder bore, such as turning, grinding, etc., it should be checked up very carefully. An expert workman, accustomed to the tool, would use an inside micrometer, but when this tool is lacking, as well as the experience necessary to use it, a fairly simple tool which can be used by almost anyone may be constructed as follows: As shown in Fig. 30, a short angle iron forms one side of the bore-measuring part; its length is sufficient to keep the entire tool perfectly vertical when the cylinder is vertical, and thus gives an accurate right-angle measurement of the bore. A central arm is fastened to this and the framework adjustably bolted to it. This includes the indicating dial at the top. At the lower corner is the indicating member, which is simply an L-shaped piece with a very short base and a very long stem; this is pivoted at the center of the bend. It is held against the side of the cylinder by means of a light spring. After adjusting the tool to the approximate cylinder bore, it is inserted, and a reading is taken; the tool is then moved, and another reading taken. The length of the arm is so great that any movement of the small arm is magnified about 15 times. In this way a difference of $\frac{1}{1000}$ in the bore shows as $\frac{15}{1000}$ on the dial, or $\frac{1}{64}$. In a shop where most of the work is on one motor,

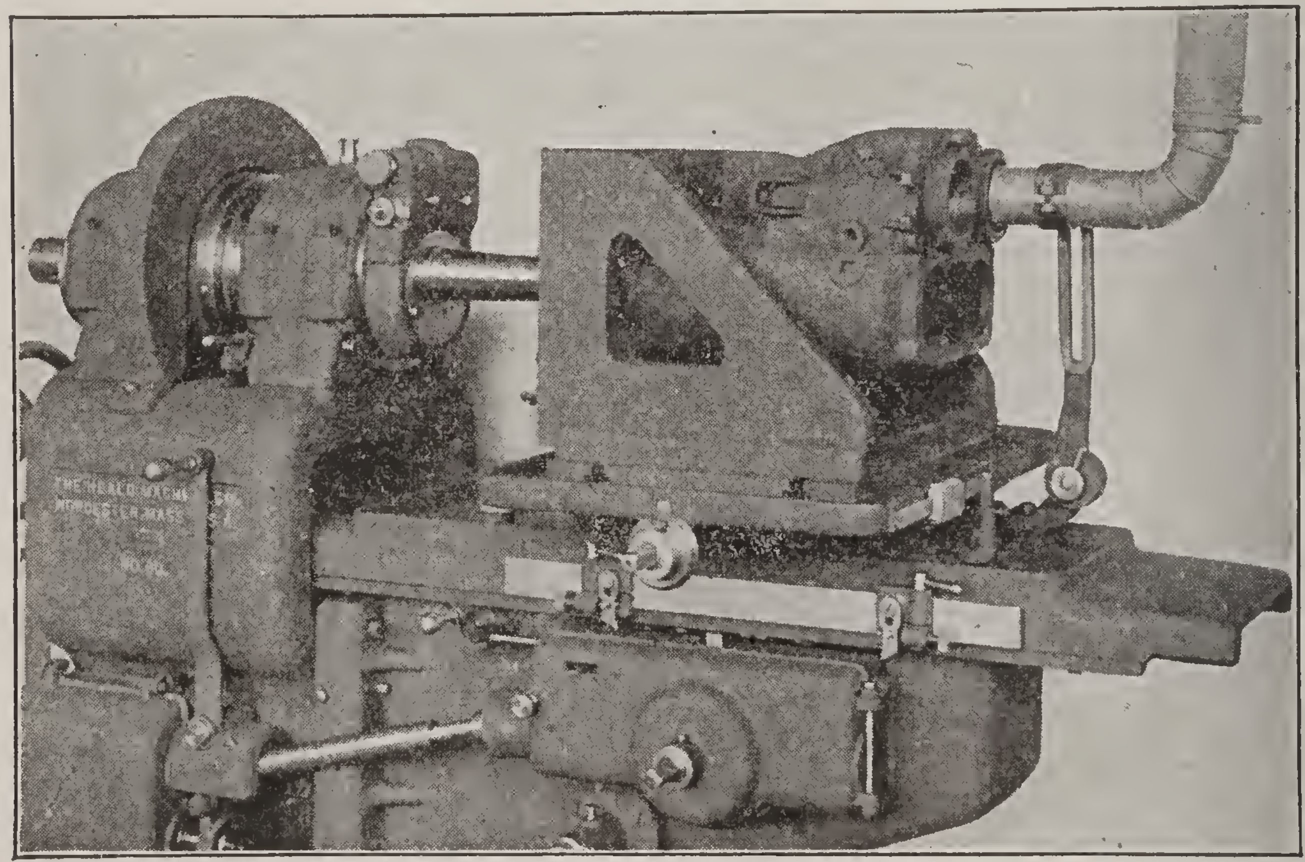


Fig. 31. Grinding Engine Cylinders
View Shows Exhaust for Dust, Jig for Holding Cylinders, and Eccentric Wheel Spindle
Courtesy of Heald Machine Company, Worcester, Massachusetts

the micrometer could be improved by eliminating the adjustable feature and making the frame and angle face a solid piece.

Grinding Out Cylinder Bore. As the usual amount of metal which would be removed from a worn cylinder would not exceed a few thousandths of an inch, grinding should be the process used. Other processes, except possibly lapping or hand grinding, are too inaccurate. For this reason, a typical grinding set-up is shown in Fig. 31. This shows the cylinder bolted against a large angle plate, attached to the grinding machine table. The angle plate is drilled out to take the bolts which hold the cylinder casting to the crankcase. When bolted up for work, the air hose is connected up through the cylinder head to blow out the dust or particles ground off. Not more than three or four thousandths of an inch should be taken off at one time; if more must be removed, a second operation over the surfaces is necessary.

If the cylinder is worn badly enough to warrant re-boring, which calls for new pistons and rings, it should be borne in mind that a standard set of oversizes has been adopted by the Society of Automobile Engineers, and that all manufacturers are working to them, by stocking pistons and rings according to these dimensions:

Oversize Standard	Inches Large
For 1st Oversize	10 thousandths (.010″)
For 2d Oversize	20 thousandths (.020″)
For 3d Oversize	30 thousandths (.030″)
For 4th Oversize	40 thousandths (.040″)

Methods of Cylinder Lapping. When the cylinder must be lapped or ground out to a true surface, not re-bored, and when no old piston is available for this purpose, there are several methods available. One is to use a standard lead lap, that is, a solid round bar of cylinder size. The abrasive may be either emery and oil, carborundum dust and oil, or, in some cases, ground glass and oil imbedded in the soft surface of the lead, yet it projects enough to abrade the

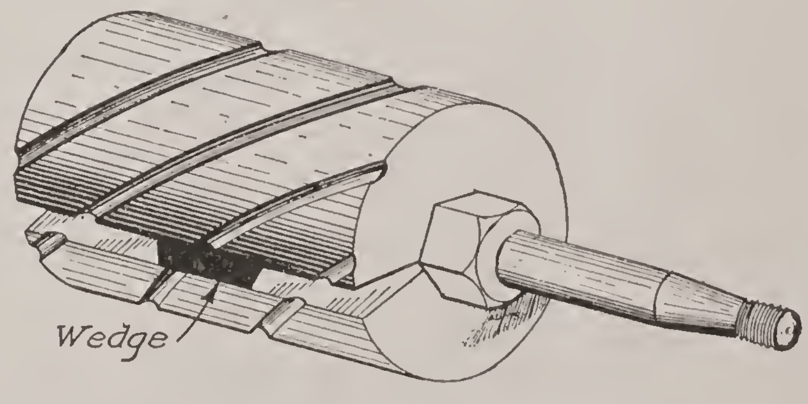


Fig. 32. Home-Made Lapper for Cylinder Bores (Note Spiral Grooves)

cylinder surface a little at each revolution. Another good way of doing this is to use a round block of wood, as shown in Fig. 32. This is made a close fit in the cylinder, with spiral grooves cut in its surface, and a split along one side. Into the latter a wedge is driven to adjust for wear. The emery and oil is put on the surface, and the lapping is done as usual. The spiral grooves distribute the abrasive evenly so that a true surface results.

Another way of doing this is to make a large special boring bar, say 2 inches in diameter, and drill a hole into this at right angles. Then, a small round section of carborundum, say $\frac{1}{2}$ inch in diameter, is placed in this hole with a spring back of it to keep it up against its work. This arrangement can be used on a lathe, the bar being rotated in the usual way, and the cylinder fed up to it either by the carriage feed or by hand. It will give a very fine cylinder surface, and use up very little of the carborundum, which costs very little to begin with. The advantage of this method is that the same outfit can be used on many different sizes of cylinders.

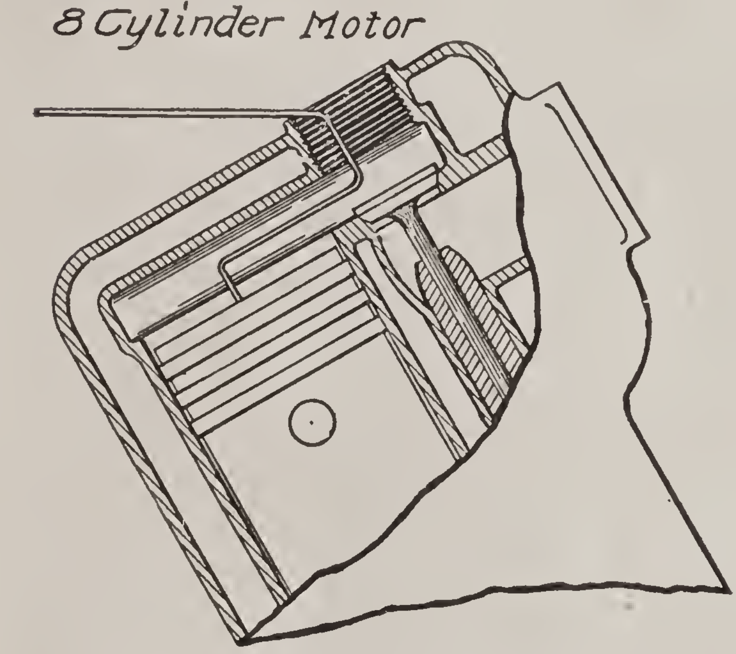


Fig. 33. Tool Made from Wire for Indicating Dead Center in V-Type Motors

Simple Dead Center Indicator. In a great deal of engine work, it is necessary to know when the pistons in the various cylinders are on dead center, either the upper or the lower center. For this purpose a form of indicator which is simple, easy to use, and accurate, is needed. A good one is shown in Fig. 33. This consists of nothing more than a $\frac{1}{8}$-inch steel wire, or narrow steel strip, bent to the form shown. It is indicated as setting into one cylinder of an eight-cylinder V-type motor, but with slightly more bending it is applicable to any form of V-type or vertical cylinder motor. The bent end is inserted, and the engine gradually turned by means of the crank until the tip end of the wire extending from the cylinder stops moving. This point is the upper dead center, and the lower center is found similarly. The advantage of the shape shown and of the long extended end is that a very minute movement of the piston is magnified and shown as a considerable movement at the end of the wire. Thus, it is possible to determine the dead center point very exactly.

Repairing Cracked Water Jackets. Very often the first cold spell of fall will catch the owner napping in the matter of heat for his motor, and will freeze up the water, which finds a weak spot in the water jacket and cracks it. When the crack is small and localized, it can be repaired very simply as follows: Drill each end of the crack as shown at *A* and *B*, Fig. 34, and screw in small $\frac{1}{8}$-inch brass plugs to prevent the crack from spreading. Then cut back the outer sides of the crack with a small cold chisel to permit inserting a considerable amount of rusting compound, being careful not to cut away any quantity of good metal. Then fill the crack up very fully and carefully with the compound consisting of two parts iron filings and one part sal-ammoniac. Just enough water should be added to this to make a paste which can be handled better than the dust or powder. After inserting, let the cylinder stand for a day or two, and if it does not seal up quickly and entirely, add a little water. If this does not complete the job, it may be necessary to go over it again, adding more of the rusting compound. After a couple of tries, almost any skillful repair man will get the hang of this job, and be able to seal a water jacket crack perfectly every time.

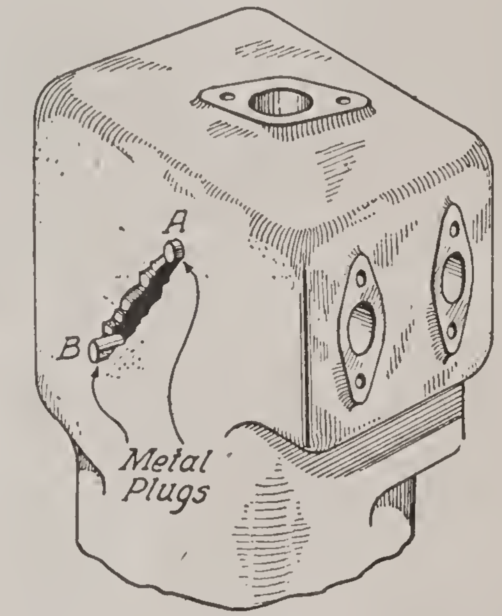


Fig. 34. Method of Plugging Small Crack in Water Jacket

Welding Breaks in Cylinders. Welding is used very frequently now on cylinder breaks, probably more than any other method, since it has proved to be quick, accurate, and cheap. It has all the desired qualities, which cannot be said of any other process. Moreover, it can be used with almost any form of metal, which also cannot be said of any other method. A separate chapter deals with welding, very exhaustively. It is recommended that every repair man study it; then get an outfit and learn to use it, for it represents a source of large profit when its use is once mastered. With a welding outfit, the method of procedure is often the reverse of other processes. Thus when a water jacket is cracked, the first operation is generally the cutting away of sufficient metal to enable the workman to see the whole extent of the crack and also to permit getting at all the surface with the welding torch. With a crack of small size, such as that just described, enough of the sides should be cut away to allow working the torch in between them. This crack should be gradually refilled with new solid metal, melted in from a fuse bar or melt bar. The sides should be cut away so as to take off more on the inside if possible, as this gives the new metal a natural hold on the inside in addition to the fusing together of the old and new metal.

When the crack is larger, but still not a big one, as a small curved or circular shape, say 2 inches long, a formed steel plate can very often be cut which exactly fits around and over the crack. This is then welded into place. This steel-plate method is particularly effective where the pieces of the water jacket are cracked out in chipping the hole or crack, or when a single piece to be welded is broken into two or three pieces during the chipping. Another similar water jacket crack repair is that necessary when the forward cylinder water jacket containing the boss in which the steel fan shaft is screwed, becomes wholly or partly cracked or broken away. This is shown, and the repair partly indicated, in Fig. 35. The difficulty here is to make a repair which will withstand subsequent tendencies to crack, that is, to make the repaired part stronger than it was in the first place. This can be done as follows: Starting at the bottom of the crack, all work proceeds upward. A hole is first burned through, as at *A*. By starting here and working upward on the right side, the hole is gradually filled with new iron from a melt bar as indicated at 2. In all this work, excess iron is left both inside and outside.

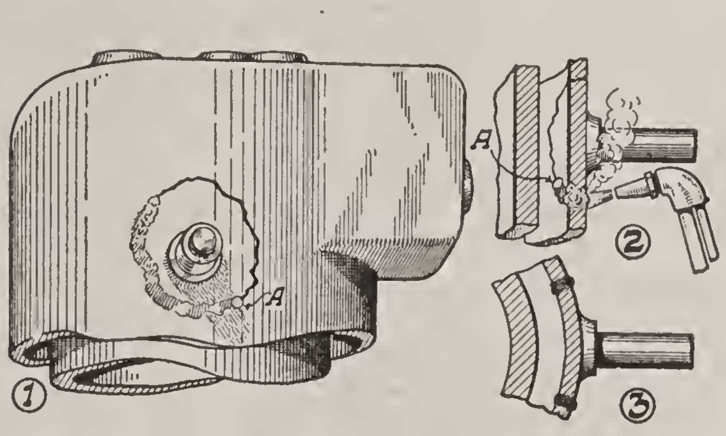


Fig. 35. Process of Welding Cylinder Jacket

Having reached the top, the work starts again at the bottom and proceeds up the other side to the top. When this is reached, and the two welds joined, the job is completed. It has the appearance shown in the sectional plan at 3, with extra metal inside and out, all around the crack. In work of this kind, precaution must be taken not to melt or otherwise weaken the cylinder wall inside.

Another cylinder weld frequently met is a flange cracked around a holding bolt. In such a break the fracture is usually confined to the flange, no part of the cylinder wall being broken or cracked. Thus, all the repair work is external, and proceeds more easily and quickly than would be the case when dealing with the more accurate cylinder wall. This is a simple repair, and is performed entirely from the outside by cutting the crack away on both sides to allow new metal to be added without increasing the thickness, then setting the piece carefully in place, clamping it there and fusing new metal from a melt-bar into the V-slot formed by chipping. In case the crack does extend to the cylinder walls or bore, it is advisable to stop the weld about $\frac{1}{16}$ inch from the interior surface of the bore. In this weld, as in previous ones, excess metal is left on the outside; in fact, this is done whenever and wherever possible, as the excess metal compensates for the somewhat brittle character of the weld and guards against a recurrence of the trouble by making the break stronger than it was in the first place.

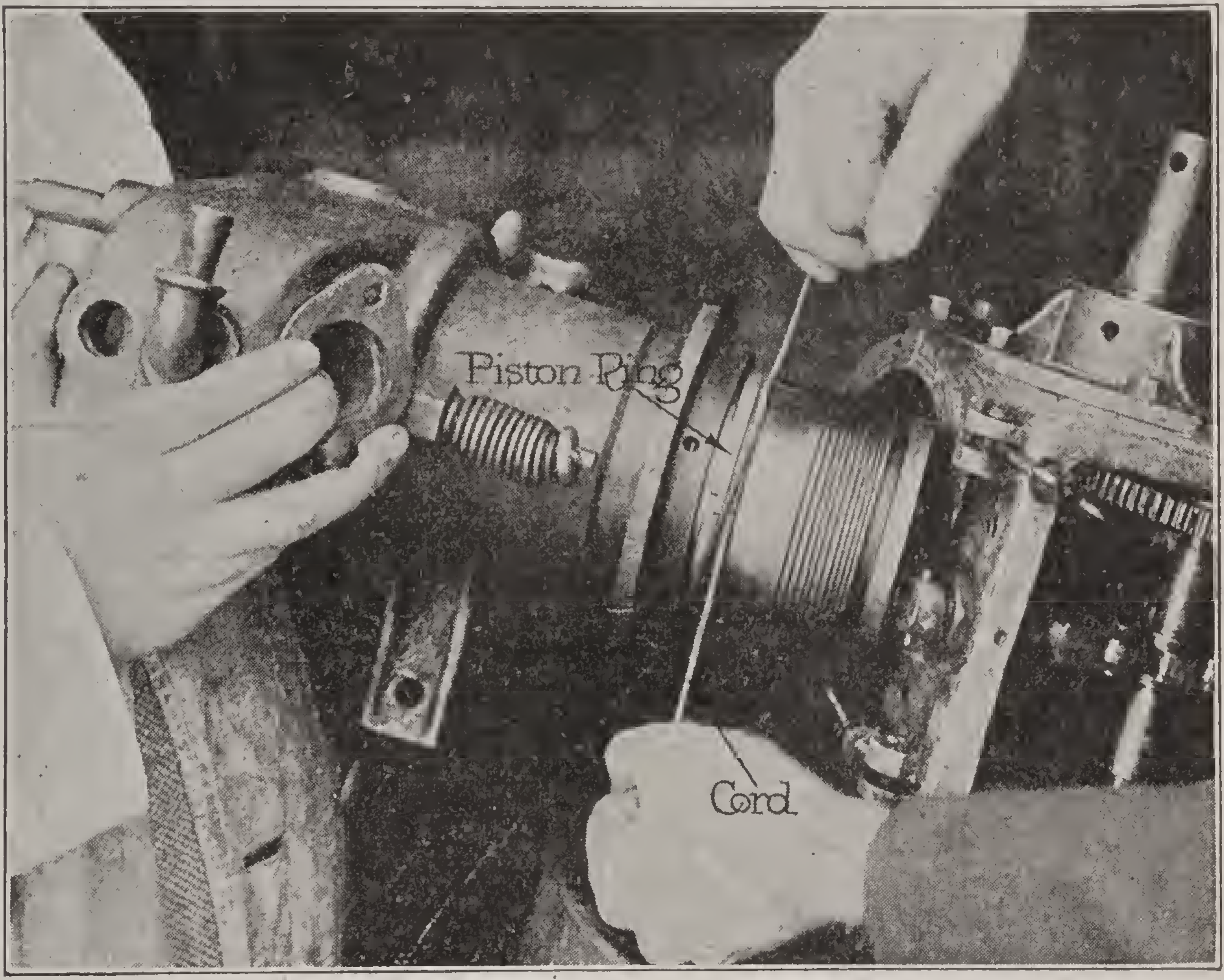


Fig. 36. Method of Re-Assembling Piston Mechanism

Working in Valve Cages. In overhead valve engines, when the valves are set in removable cages, it is often necessary to put in a new cage. This is worked in or seated in the cylinder by grinding it down to a perfect seat the same as a valve. Oil and emery are placed on the seat in the cylinder, the cage set in place and gradually worked around and down, until a perfect surface is obtained. The same is applied to renewing the seat when a valve cage shows signs of leakage.

Replacing Pistons in Cylinders. When cylinders or pistons have been removed to be worked on, replacing these is a difficult job. There are two ways of doing this: viz, by a special form of ring closer, and by hand, using a string. The former is a shaped device which is clamped around the ring and squeezed together with pliers, using one hand, while with the other hand the ring is guided into the groove. The second and more usual method is illustrated in Fig. 36, and requires two men, unless the cylinder is of such a shape that it can be clamped in a vise. As the picture brings out, one man holds the cylinder while the other forces the piston carrying the rings into place. The piston is shoved in until the expanded top ring prevents further movement, when a heavy cord is placed around the spring, and the ends are crossed, thus closing up the ring and allowing the piston to slide in as far as the next ring. The operation is repeated successively for the other rings. This is a very simple method but it requires patience.

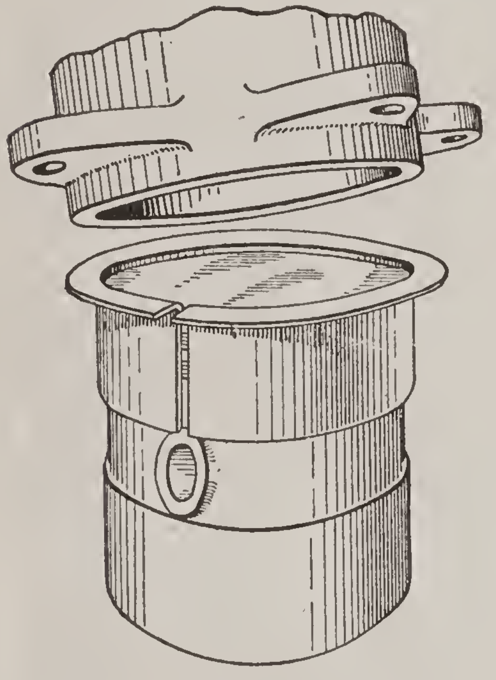


Fig. 37. Simple Rig to Assist Pistons Entering Cylinder Casting

When a block cylinder is to be replaced, this job is not so easy, for all the pistons, four or six as the case may be, must be lined up, and two of them entered at one time. This requires either special apparatus to help hold them or the services of several men. Most cylinders have a small bevelled edge at the bottom to facilitate this, but it is best to make a rig for a motor which is handled in sufficient numbers to warrant this. A handy form, and one easily made, is that shown in Fig. 37. This consists of a sheet-iron band of a depth equal to the total depth of the rings in the upper part of the cylinder and is flanged over at the top to give it extra stiffness and prevent its entering the cylinder. It is made a little bit small for the size of the pistons over which it is to be used, so it will have to be sprung into place. When this is done, it will have a tight hold on the rings, compressing them so they will enter the cylinder. In applying it, care should be used to put it on squarely, and similarly in pushing it down by forcing the piston upward into the cylinder, as it should not be moved off of a ring until that ring has been entered in the cylinder enough so it is held therein. That is, the spring clamp should not be moved down below a ring until that ring is engaged and held within the cylinder. Its use is restricted to one size of motor, which is no hardship in a big shop where one make of car is handled exclusively. The small shop handling a variety of work would find half a dozen different sizes useful and economical. Moreover, the cost of this device is very small.

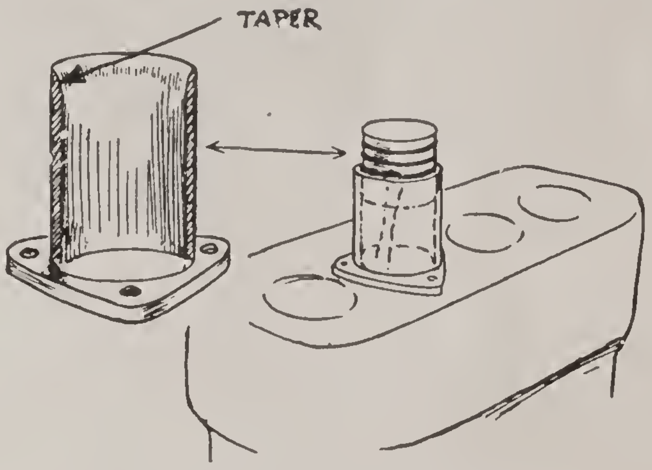


Fig. 38. A Simple and Easily Made Jig for Replacing Pistons in Detachable Head Motors

A modification of the above device consists of a similar small-size band of sheet metal, made very wide, but without the upper flange. It is made, however, with a pair of right-angle lips where the two sides meet, these are drilled for a clamping bolt. This bolt has a wing nut with clamping rings to compress the lips. Another modification of the above is a loop or strap of narrow sheet metal having an additional loop to go over the two ends. These ends are made with a right-angle bend close to the piston-curve portion, and the compression of the rings is effected by pressing the sides of the clamp tightly against them, then sliding the small loop along the ends to hold this tightness.

Rigging for Replacing Piston. In motors of the detachable-head type, like the Willys, the Chalmers, the Briscoe, and others, the work of replacing the pistons, particularly if the crankcase is cast integrally with the cylinder block, is considerable. In fact, it is sufficiently difficult to warrant making a special jig for guiding the pistons down into the long cylinder bores; this fastens onto the top of the cylinder where the head belongs.

As shown in the sketch, Fig. 38, the jig consists of a round shell, the interior of which is at the bottom of the same bore as the cylinder, but flares out considerably at the top. The base consists of the flange needed for turning this in the lathe and may be of any shape, size, and thickness. The action of the enlarged diameter at the top, gradually tapering to the exact cylinder size at the bottom, is to hold the piston rings in place and slowly contract them as the piston is lowered, so they pass down into the cylinder bore without trouble. One casting must be made for each cylinder bore, but the time and trouble which they save, and the injuries to workmen and parts which they avoid, make them well worth while.

PISTONS AND ACCESSORIES

Piston Construction. The pistons of automobile motors have long been made of cast iron, with the piston pin held in bosses on the piston walls. For all ordinary service this construction, well carried out, serves every purpose, but with the development of very high-speed motors, with piston speeds twice and three times as high as past practice has sanctioned, there is a growing tendency to substitute steel for cast iron in this important reciprocating element.

Particularly in aviation motors has this been the case; the pistons of one well-known revolving motor, for example, are machined to the thinnest possible sections, out of a high-grade alloy steel. In this motor, the connecting rods are hinged to the head of the piston instead of to the walls, which can be made much thinner than otherwise would be possible. This practice has been followed to a slight extent by some automobile manufacturers. There are now a few stock cars of established quality provided with pressed-steel pistons.

In cars, too, the movement toward smaller bores and higher efficiency has brought about the use of much lighter pistons; this is done by making them thinner and shorter. The latest development has been the use, not only of aluminum pistons and die-forged aluminum alloy connecting rods, but also of aluminum cylinders having cast-iron sleeves driven in to form the actual cylinder surfaces.

Modern Tendencies. The modern tendency is to cut down the weight. This has been done by lightening the piston all over and by taking out rings. With fewer rings, it is necessary that each should be more efficient, consequently there has been much experimenting done with new forms. The lightening of piston weight has not materially changed the old open-end trunk form, although the use of aluminum has modified its straight shape somewhat in the hourglass and similar forms. Attempts to utilize so-called free pistons, in which the upper part is flexibly connected to the lower, and the use of combinations of pressed steel and other metals have done much to modify the general form.

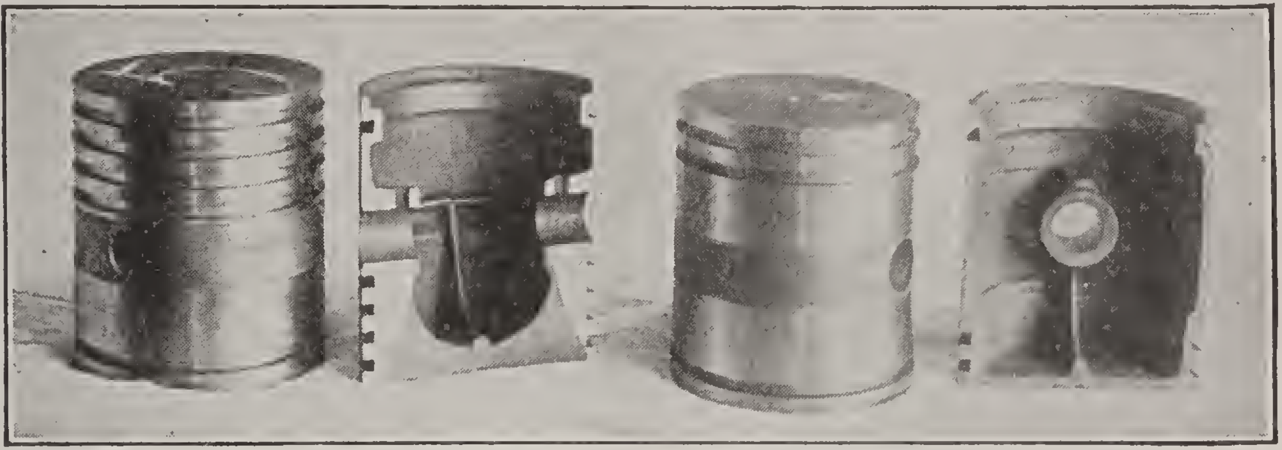


Fig. 39. Old and New Types of Pistons
Former Heavy Piston at Left; Present Lighter Type at Right
Courtesy of Locomobile Company of America, Bridgeport, Connecticut

Both these tendencies are well shown in the illustrations, Figs. 39 and 40. The former shows how a certain piston was lightened by taking out two rings at the top, one rib inside, and generally using thinner metal. The old form is shown at the left, the new at the right. The other tendency is seen in Fig. 40 which is an aluminum alloy. Note how this is cast to have less metal at the piston boss and also to be strong without extra ribs.

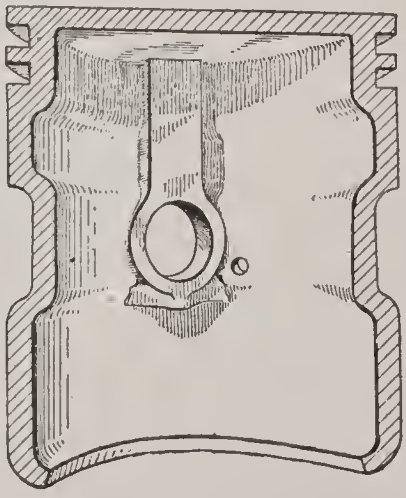


Fig. 40. Typical Piston Cast in Aluminum Alloy for Minimum Weight

Characteristics of Piston Rings. Cast iron for piston rings, long used to the exclusion of everything else, is in slight degree yielding its pre-eminence for this purpose also. This is because it has been found, in aviation motors with steel cylinders, that bronze affords greater durability and smoother running against the steel-cylinder wall, for which reason bronze rings—with steel or cast-iron springs, or "bull rings", behind them—have been found most advantageous. Multiple rings, three or more in a groove, are finding favor. Their thinness necessitates the use of steel.

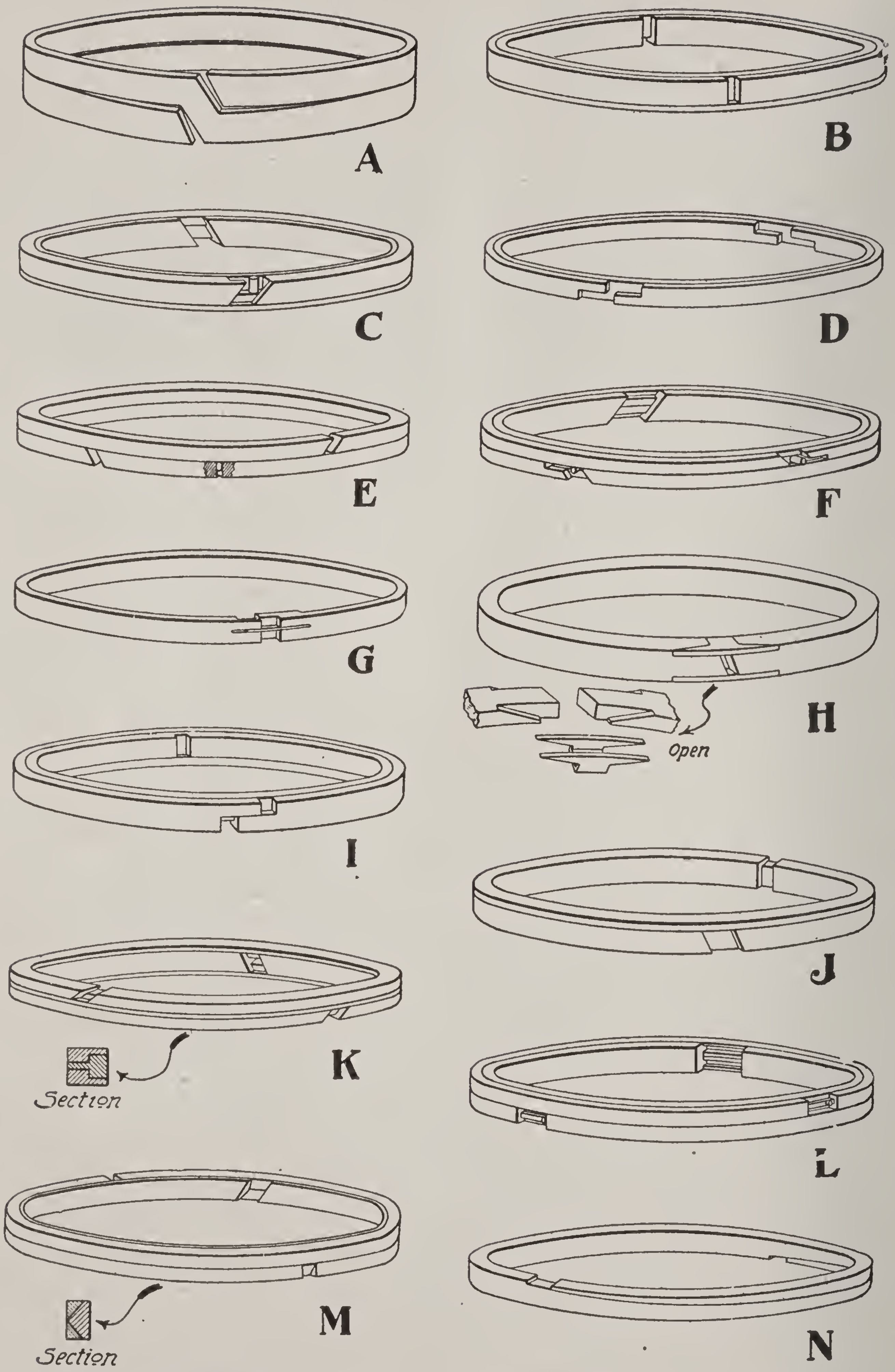


Fig. 41. New Types of Piston Rings Designed to Retain Compression and to Increase Power, at the Same Time Reducing Wall Friction

Types of Piston Rings. Where formerly three or four plain rings were used, each one filling a groove, many pistons are now equipped with multiple rings of various patented forms, for which many advantages are claimed. Some idea of the variety of these may be obtained from Fig. 41 which shows a number of different forms.

Thus, *A* indicates a ring with a double form, yet really it is one continuous piece, cut so as to appear as two. It is difficult to see any advantage in this, while it is much more expensive than the old-fashioned form. At *B* is seen a type which has an outer thin but high ring within an **L**-shaped inner form, both with plain vertical slots, and without holding pins of any kind. A somewhat similar form is seen at *C*, but with this difference, the inner ring has two steps instead of one, both have diagonal slots, and a pin keeps the outer one from turning.

The form at *D* has a pair of thin and very flexible high rings, set one within the other. They are concentric, and both have stepped joints. The extreme flexibility would appear to take all the value out of their use as compared with the ordinary form. Another seen at *E* differs in that one part is placed above the other and held from rotating by a pin. Both have diagonal joints. Both are eccentric and the pins hold them so the slots are 90 degrees apart. In the form at *F*, there are three pieces, including an inner one of full height with a deep outer slot, a modified **U**. The two outer parts are **L**-shaped and the **L**-projections fit into the slot of the big ring. All have diagonal slots and are pinned in place.

An eccentric form, which has a tongue-and-groove arrangement at the open or thin end, is shown at *G*. The makers call this the lock joint. Practically the same effect is produced in the form shown at *H*, except that the opening is closed by a separate piece. This is called a guard, and it is machined to fit under one portion of the master ring and on either side of the slender ends, so that it makes up the full width. This use of the old-fashioned simple ring seems good.

The form at *I* is that of *B* reversed, that is, the small square ring is placed on the inside of the **L**-shaped ring, and has, in addition, a horizontal step joint, while the outer member has a vertical step joint. An entirely different principle is utilized in the form at *J*, the inner **L**-shaped member having a taper, and the outer thin but high member having a corresponding taper to fit against it. The idea of the taper is that the spring of the two rings, slightly opposed, will work through this to hold both against the cylinder walls. The outside of the inner ring is knurled to hold the outer one from rotating. Both have diagonally cut slots.

In the form shown at *K*, there are three parts, divided vertically, but in such a way that the top and bottom are really dependent upon the middle to hold them in place both vertically and horizontally. It is difficult to see greater merit in this form than of three plain rings. The form at *L* is somewhat like that at *F*, except that the inner full-height ring has a pair of projecting ridges in place of the single central slot. Each of the small half-width outer rings has a central slot, or groove, and end ridges to fit around this. Like *F*, this has the small outer rings pinned, but differing from it, all have diagonal slots.

In the form seen at *M*, three parts are used, but the center full-height piece has its outer surface in the form of a double taper, upon each half of which one of the small half-height outer rings of triangular cross-section rests. In that shown at *N*, the ring is a continuous spiral, being somewhat similar to *A* in this respect. Its cut, however, is upon a slope all the way, so that its thickness varies continuously. It is made of heat-treated steel. It is difficult to see how the vertical spiral effect can make it tighter in a horizontal direction.

Piston Pins. Piston, or wrist pins, as they are variously called, are usually very simple. In general, when the pin is a light drive fit or any easy fit in the piston, it is made from a high quality of carbon steel tubing of considerable thickness, ground on the outside to size, and drilled for the locking pin (when one is used). It is then hardened and finish ground. In some instances it is simply a tight fit, with a ring fitted around the outside of the piston at its center, to form a lock. In other forms it is clamped in the connecting rod and turns in bushings in the two piston bosses. The general method, however, is the use of a hollow pin, the variation coming in the method of locking. Thus there is the use of two locking pins which project into holes; of two set screws which bear against grooves for this purpose; expansion plugs screwed into the split ends; spring plungers in holes in the piston; and of complex built-up pin sections with tapers bearing upon each other so as to be self-locking. The really important point is to have the pin so locked in place that it can never work out and score the cylinder walls, and yet be easy to disassemble.

Piston and Ring Troubles and Repairs

Removal and Replacement of Pistons. Speaking of pistons, there are several things that the beginner should learn about their removal and replacement. While it is not a difficult matter to pull a piston out of a cylinder, when both have been previously lubricated, and all proper precautions taken to loosen connecting parts, there are a few important things to remember.

The piston should be drawn out as nearly parallel to the axis of the cylinder as is possible, accompanied by a twisting motion not unlike taking out a screw, in case it sticks a little. If the piston sticks badly, pour in a little kerosene and work the piston in and out so as to distribute the kerosene between the two surfaces.

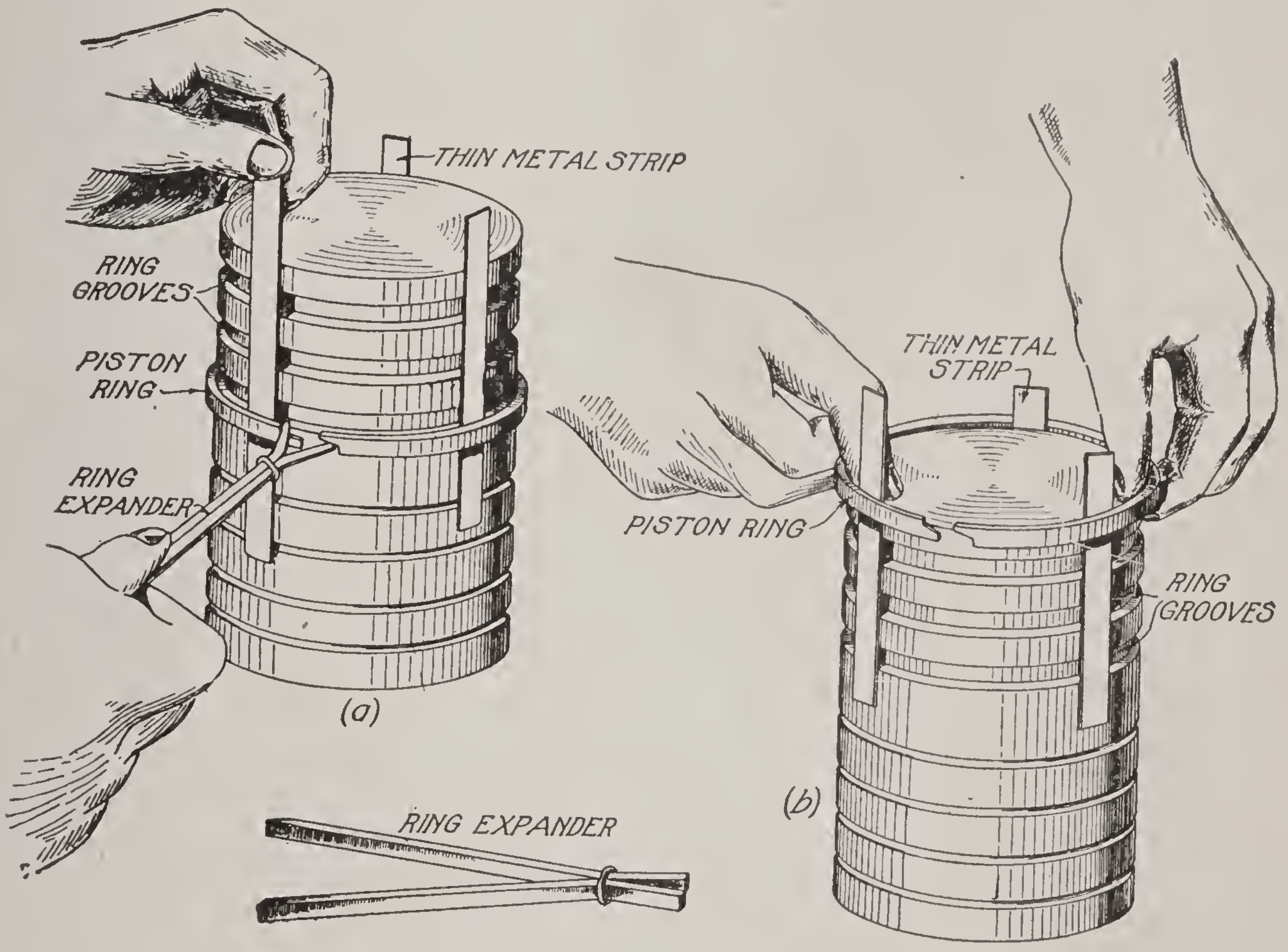


Fig. 42. Method of Removing Piston Rings

To get at the spaces the rings must be removed, and as they are of cast iron and very brittle, this is a delicate task. Two methods of accomplishing this are illustrated in Fig. 42. If the owner has a pair of ring-expanding pliers, the rings can easily be expanded enough to lift them over the edge, as shown in (*a*). As very few owners possess this useful tool, however, a more common way is shown in (*b*). Secure a number of thin, flat steels about

$\frac{1}{2}$ inch wide and $\frac{1}{16}$ inch thick—corset steels, flat springs, or hack-saw blades may be used, although the latter require more care on account of the teeth along one edge. The length of these steels should be such as to reach from about an inch below the last ring, to the top. Lift out one side of the ring with a small pointed tool and slip one of the steels between the ring and the piston, then move around about one-third of the way and insert another, taking care to hold the first in place; repeat the operation with a third steel. When these are in place, the steels will hold the ring out from the piston far enough to be slid over the "lands" between the grooves and along the steels to the top.

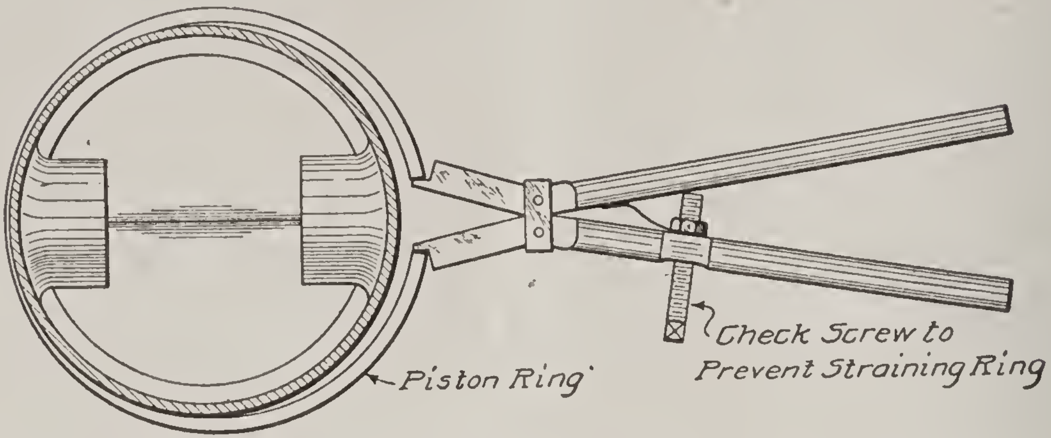


Fig. 43. Tool for Moving Piston Rings Which Prevents Breakage

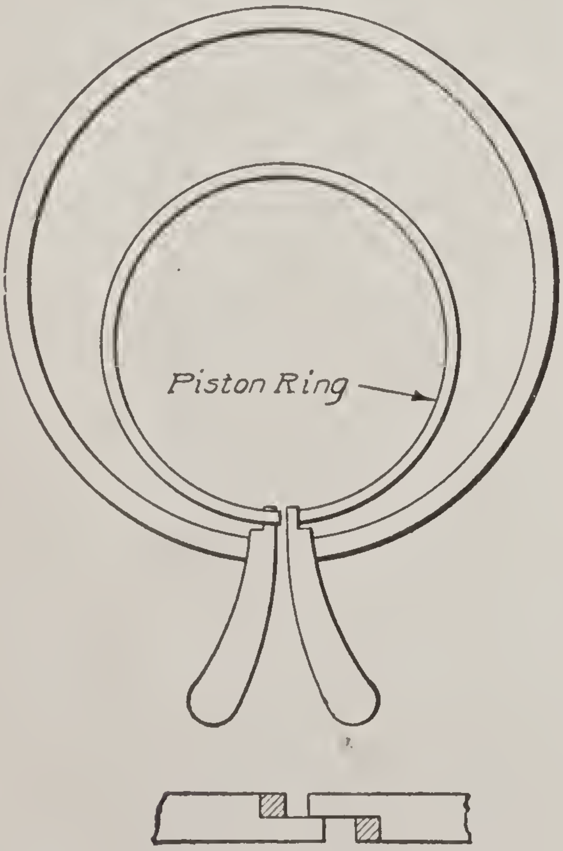


Fig. 44. Simple Piston Ring Remover

Always begin at the bottom and work up when removing rings, and just the opposite, from the top down, when replacing them. After one is mastered, the removal of the others is a simple matter of repetition. The grooves can now be scraped free of the offending carbon, a process which is but an inversion of the previous method. After this it will be necessary to replace the rings.

A modification of the simple home-made ring spreader just shown is that depicted in Fig. 43. This is made with a stop, which prevents opening the pliers beyond a predetermined distance and thus prevents breaking a ring by continued pressing on a stiff or stuck one until it gives suddenly and is then spread beyond the resisting ability of the iron. It is applicable to all forms of rings, except those with diagonal slots. In addition to the construction shown, it is desirable to fit a spring which will draw the handles together when not in use. This closes the jaws and keeps them closed, ready for immediate use.

An even better and more simple form, but without the safety feature of that just mentioned, consists of a large diameter steel spring, shaped not unlike a very big piston ring, which has a pair of handles fitted to the ends. This is shown in Fig. 44, which indicates how the nubs on the two handles are shaped so as to take hold of stepped joint rings. By making these nubs differently, any form of ring can be handled. A device of this sort saves the repair man lots of time.

Loosening Seized Pistons. When the pistons and rings freeze into the cylinder, or seize because of a lack of lubricant, there is nothing quite so good nor quite so quick acting as kerosene. The cylinder head should be opened as quickly as possible, and the kerosene poured in liberally on top of the pistons. This should be done in each cylinder. Kerosene is thin and will work down between cylinder wall and piston rings, gradually cutting away the two where they have frozen together. If kerosene is not available, take the thinnest lubricant at hand; heat it so that it will be still thinner and more penetrating, then pour it in. At times, olive oil can be combined with kerosene to advantage.

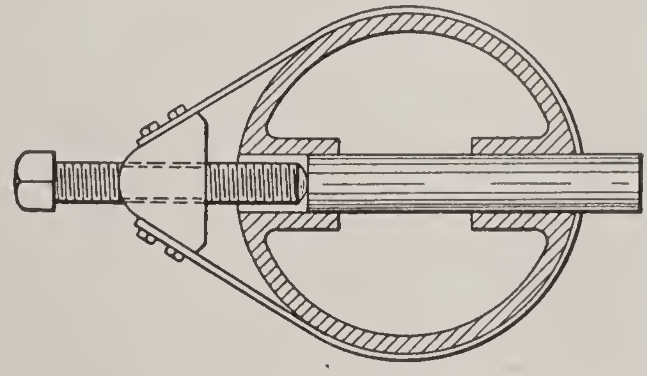


Fig. 45. Simple Piston-Pin Pulling Outfit

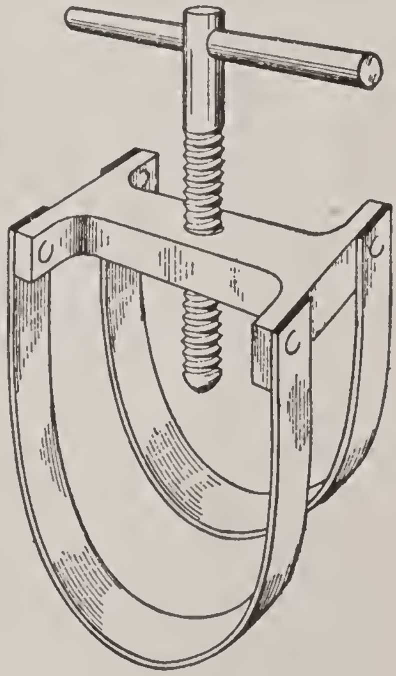


Fig. 46. Piston Ring Puller Which Allows for Exit of Pin

Freeing Wrist Pins and Bushings. When the piston pin or wrist pin is inserted directly in the piston, it is usually a tight fit, so tight, sometimes, that the repair man experiences difficulty in getting it out. To overcome this difficulty, a piston pin puller is needed. One of these, shown in Fig. 45, is made from a piece of steel, a steel strap, and a large cap screw. This piece of steel is drilled and tapped for the cap screw, and for the bolts to hold the steel strap. Then the latter is fastened so as to be about ¼ inch larger in diameter than the piston, or still larger if a long cap screw is available. When a pin is to be removed, the strap is put around the piston and the cap screw screwed in until it bears against the end of the pin. This can be done by hand. Then a wrench is applied, and as the screw is forced in, the pin is forced out on the opposite side. Be careful to see that the far side of the steel band is below the piston pin hole, so the pin will be able to come out without touching it.

This can be simplified by having an endless steel band with a nut on the inside of it to form a backing for the cap screw to work against, or, the steel band can be welded to the nut.

A form which removes the above difficulty is that shown in Fig. 46. This is made so that it holds around the piston at two points, above and below the piston pin, leaving room for the pin to come out. While more elaborate than the first one described, it is still very simple. For hollow piston pins, a different form of tip on the screw is needed, as the point, or tip, must press against the outer circular ring instead of against the center. This can be obviated, however, by laying a special round piece of metal over the end of the hollow pin before starting to apply pressure to force it out.

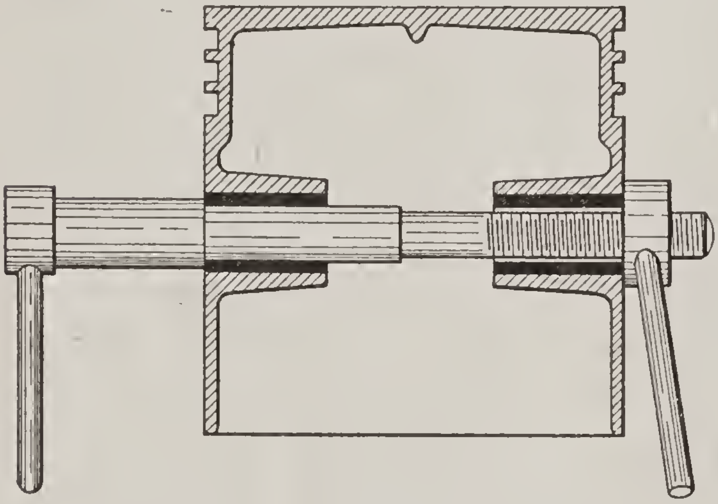


Fig. 47. Piston Pin Bushing with Shouldered Mandrel

Bushing Removers. When the piston pin is fixed in the connecting rod and rotates in bushings in the piston bosses, it is sometimes necessary to remove these bushings. A somewhat similar device will do this work, except that a shoulder or stop is needed to come up home against the side of the bushing, while the screw or threaded end must be small enough to pass through the hole in the bushing, and long enough to come out on the other side so a nut can be applied. One of these is shown in Fig. 47. The disadvantage of this type is that the nut shown on the right, which is operated to force the bushing out, must rest against the surface of the piston while being turned around. If a small U-bar be made to rest against the piston side, with a central drilled hole through which the threaded end passes, the nut will bear against the outside surface of this, so that even if the nut should scratch, no harm will be done to the piston. These pullers are used as substitutes for an arbor press, but this is desirable, as the use of the press is likely to distort the more or less delicate piston. With aluminum and the lighter weight cast-iron pistons, this is a thing which it is desirable to avoid.

Some motors have the wrist pin locked in place by means of an expanding nut with a sunken square hole for turning. To start these, a wrench with a square projection or tit to fit this is needed. Such a wrench is used on certain lathe chucks, so one can always be borrowed in a machine shop or tool room.

Mandrel for Turning Pins. Because of its being hollow in many cases, the wrist pin is difficult to handle when any work must be done upon it. For this purpose, a mandrel is needed. The method of constructing and using this is shown in Fig. 48. This consists of a shaft with a taper at one end and thread at the other, for a tapered nut. The wrist pin is slipped on the outer end, the taper nut put in place against it, and the backing nut put on behind that. Then these are screwed up until the two tapers hold the pin firmly, after which it may be placed in the lathe and work done upon it.

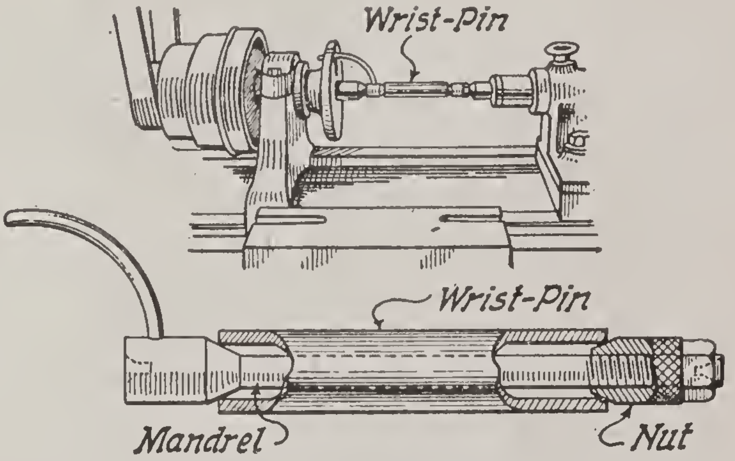


Fig. 48. Tapered Mandrel for Holding Hollow Piston Pin for Lathe Work

Speeding Up Old Engines by Lightening Pistons, Etc. As will be pointed out later under "Cams", one way to speed up an old engine is to replace the old camshaft and cams with new ones giving more modern timing. Another and a less expensive and troublesome way in which this can be done is by lightening the pistons and the reciprocating parts. This the repair man will surely be called upon to do, as the manufacturer probably would refuse.

In order to get out any amount of metal worth the trouble, it will be necessary to drill from 12 to 20 or more holes of from $\frac{1}{2}$-inch up to 1-inch diameter, depending upon the size of the piston as to bore and length. In a six-cylinder motor, this amounts to almost 100 holes (even more in some cases), and as these must be drilled with considerable similarity in the pistons, it is well worth while to construct a fixture to aid or speed up this work.

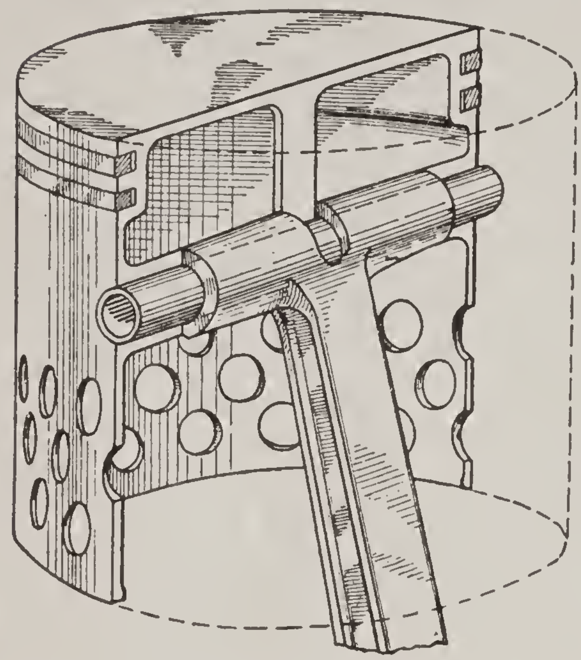


Fig. 49. Appearance of Piston Lightened for Racing Purposes

One idea of the way such a lightened piston should look when finished is given in Fig. 49, which shows the steel pistons used in the Sunbeam racers. These are made this way to give the maximum of lightness with strength. Although made from steel, this is done simply to get very light side walls, and the general appearance of the skirt with its many drilled holes is just what the repair man should try to get when he starts to cut down the weight of standard pistons for racing or speed purposes.

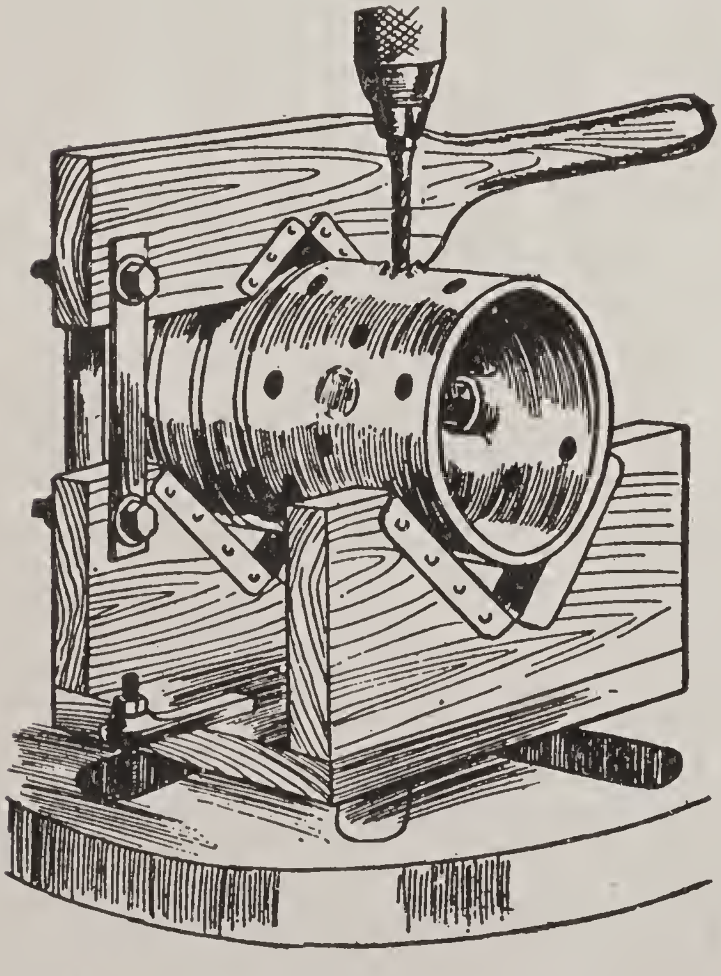


Fig. 50. A Home-Made Wooden Stand to Facilitate Drilling Out Pistons

Clamp for Pistons. The first requisite is a clamp, Fig. 50, to keep the piston from turning, so that it will not break the drill. A good way to begin is to construct a base with a pair of uprights having deep 90-degree V's in them; this is made so that it can be bolted to the drill-press table. The V's should be lined with leather or fabric. Discarded clutch or brake linings answer this purpose very well. To one of the uprights is pivoted a long handle, having a lined V which matches with that of the upright below it, and gives a good grip on the piston.

Drilling Holes. When drilling to save weight, the holes are put in close together and in regular form, the idea being to take out as much weight of metal as is safe. In doing this, it is well to work out a scheme of drilling in advance, to make a heavy brown paper template, and fasten this to each piston in turn. It is not advisable to remove all the metal possible at first, but only enough to show the benefit of the method; after it has proved satisfactory, the first job may be improved upon later. For instance, in lightening pistons, it is a good plan to use a $\frac{3}{4}$-inch drill the first time, and not to put in too many holes. If this proves satisfactory, and the owner comes back for more, you can go over the same lot of pistons, using a $\frac{1}{2}$-inch or $\frac{3}{8}$-inch drill between the existing holes, and thus reduce the weight of the lower end of the piston to its lowest possible point.

Testing Size of New Piston. A skilled repair man gives the following suggestion relative to trying new pistons for clearance: When not certain whether the new piston will give sufficient clearance, heat it to about 600° F. If it is a snug fit in the cylinder, it probably will give satisfaction under normal running conditions. This, of course, is only approximate as the cylinder would heat up in use and expand but it serves the purpose and is quickly and easily done.

Non=Leaking Rings. Another repair man says that when the rings get old, they can be made compression proof by grinding down so that two old ones will occupy the space formerly taken by one. This would work well for the top groove with a new ring lower down.

Sometimes a ring will get broken when no others, either old or new, are obtainable. In such a case, the ring can be welded, if unusual care is exercised not to melt away any of the metal.

When rings must be turned in the lathe, either for reducing the thickness or for truing up the face, a wooden face plate should be made with a slightly tapered groove for the ring to fit into. The ring should be pressed into the groove, and its natural spring will hold it in place. When working on the outer diameter, the face of the wood will have to be cut away sufficiently to allow the ring to project, or, instead of a single large central hole, an annular ring can be turned in the wooden face plate, the ring being fitted over the outside of it.

Tracing a Ring Knock. Many times there is an elusive light knocking or chattering in the motor, especially at low speeds, which cannot be run down. This is often due to piston rings wearing at the top and bottom so they are loose in their grooves. When the piston moves upward, these rings remain stationary until they strike the bottoms of their grooves; when it moves downward, the rings strike the tops of the grooves. At low speeds, these noises can be distinctly heard; but at higher speeds, they are so faint that they blend off into the general murmur of the engine. Another noise, which comes from the rings, is that due to weakness or loss of spring. This is shown by a sharp rapping somewhat like a piston slap, when the throttle is opened suddenly. If the rings, and especially the top ring, are not stiff enough to resist the compression and explosion, this force will compress them. At the end of the stroke, they will expand suddenly against the cylinder wall, causing the rapping described. A notch filed in one edge so the pressure can leak in behind the ring will help matters, although new rings are better.

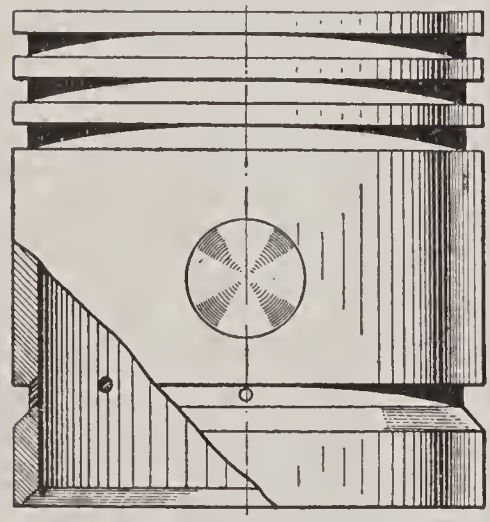


Fig. 51. Method of Grooving and Drilling Piston to Overcome Excessive Lubrication and Smoking

Curing Excessive Lubrication. *Holes in Pistons.* When it comes to drilling holes to provide an outlet for the excess oil in the cylinders and so to reduce smoking, small holes, $\frac{1}{4}$-inch for example, are sufficient. They may be drilled in on any spiral plan by simply beginning near the bottom and working up close to the piston-pin bosses along a spiral track. The advantage of the spiral arrangement is that no hole is above another; the dripping from each hole is therefore distinct, and the quantity which runs down is greater.

Grooving Pistons. Another method of curing the excessive lubrication to which the older cars—particularly those with splash lubrication—are subject, is to turn a deep groove in the bottom of the piston, about like a piston-ring groove but with the lower edge beveled off. When this is done, much as shown in Fig. 51, a series of small holes—made with a No. 30 drill—are put in at the angle of the bevel; 6 or 8 holes, equally distributed around the circumference, are probably enough. The sharp upper edge acts as a wiper and removes the oil from the cylinder walls into the groove, whence it passes through the holes to the piston interior and there drops back into the crankcase. No ring is placed in the slot as it would prevent the free passage of the oil. This device stops the smoking immediately.

Loose Pistons. Many times the pistons will wear just enough so that they are loose in the cylinder all the way around. This causes leakage of gas, piston slaps, and other similar troubles. If the owner of the car does not care to buy new pistons, or if the car is an "orphan", or if, for other reasons, pistons cannot be obtained, the clever repair man can remedy the trouble at small expense. The process consists in heating and expanding the old pistons. The heating is done in charcoal and must be done very carefully and slowly. After the pistons become red hot the fire is allowed to go out slowly, so that the piston is cooled in its charcoal bed. Sometimes as much as $\frac{4}{1000}$ of an inch can be gained in this way. When the pistons are so far gone that they cannot be handled in this way, they must be replaced with new ones.

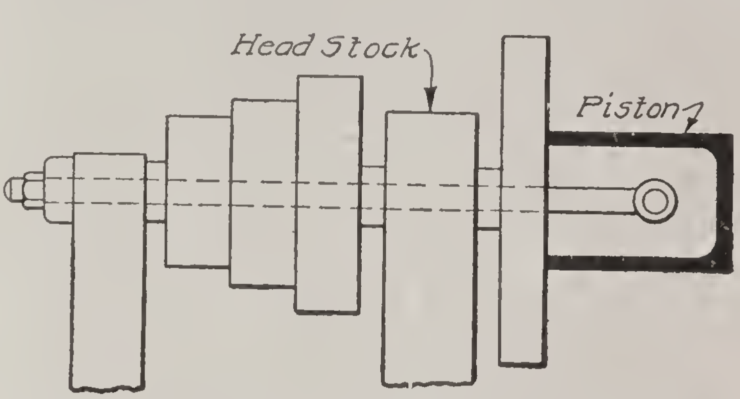


Fig. 52. Rigging for Holding Piston against Face Plate of Lathe

Mounting Pistons on Lathes. It is difficult to handle a piston in the lathe, or machine the outside in any manner, as a chuck does not get enough of a hold on it, and is likely to mark the surface. When work on it is necessary, the piston can be handled effectively by using a small rod with an eye at one end. This is made to fit the piston pin in the case of an old piston. The rod is run through the hollow spindle and bolted at the outer end. The tightening of the nut on it pulls the piston up against the face plate as Fig. 52 shows. This same method can be used when making a new piston. In the latter case, it is held in the chuck to finish the outside and inside, then the wrist-pin hole is drilled, bored, and reamed, and the wrist pin fitted. Finally, the finishing cut, or grinding of the outside, is completed.

CONNECTING RODS

Design Characteristics. *H-Section Form.* Established practice in connecting-rod design is almost all in favor of the common

H-section rod, usually with two bolts to attach the cap. In some cases four bolts are used, since with four bolts a flaw or crack in one is less likely to cause damage than is the case when only two are used. The old scheme of hinging the cap at one side is now practically obsolete, having been discarded because it made accurate adjustment of the bearing surfaces almost impossible.

Tendency to Lighten Rods. The modern tendency toward lightening the weight has extended to the connecting rods, since a portion of the rod is considered as reciprocating. This lightening has been accomplished by external machining. Thus, in the typical connecting rod of forged alloy steel, shown in Fig. 53, the form at the left is that formerly used, while that at the right is its present shape. Note how the rounding sides of the **H**-part, necessary in forging, have been machined off; how the fillets at big end and piston end have been machined down; how the upper end has also had its central rounding part machined off; and the whole, file finished. Another excellent feature of the work done to lighten the rods in this way is that they can be brought to an absolute standard of weight, so that every rod weighs exactly the same as every other. This was not possible previously, as the variation of the exterior surfaces, due to differences in forging, made considerable difference in weight. In both, the bushings are in place.

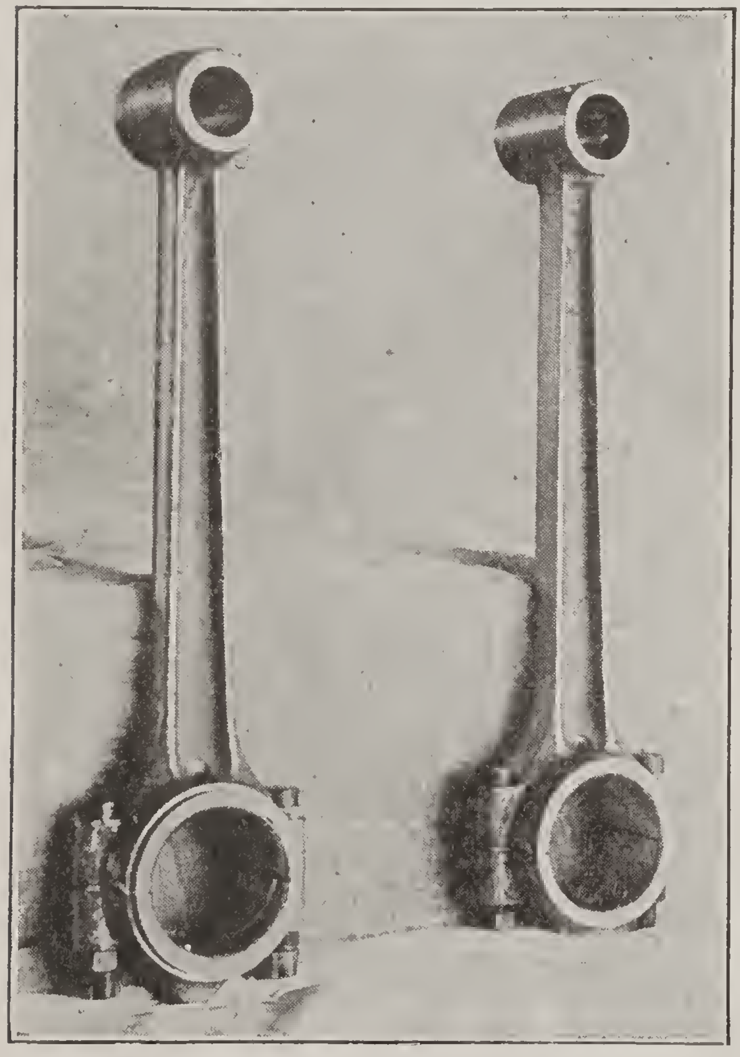


Fig. 53. Old and New Connecting Rods Showing How They Can Be Lightened
Courtesy of the Locomobile Company of America, Bridgeport, Connecticut

Tubular Rods. Tubular rods, in place of the **H**-section, are giving good service in several of the long-stroke foreign motors, and it is difficult to see why this form is not superior to that in common use.

The question of cost, however, is a consideration, since it is necessary to bore the hole through the inside of the rod, whereas a forged rod of H-section requires no machining except at the end.

The wonderful progress in welding, however, has made it possible to construct a tubular connecting rod at a very low expense, and, owing to its many advantages, this is finding much favor for small motors. The two ends are machined and a section of tubing welded to them.

One advantage of the tubular rod, in addition to its superiority for withstanding the compression load to which a rod is chiefly subject, is that it can be used as a pipe to convey oil from the big end to the piston-pin bearing.

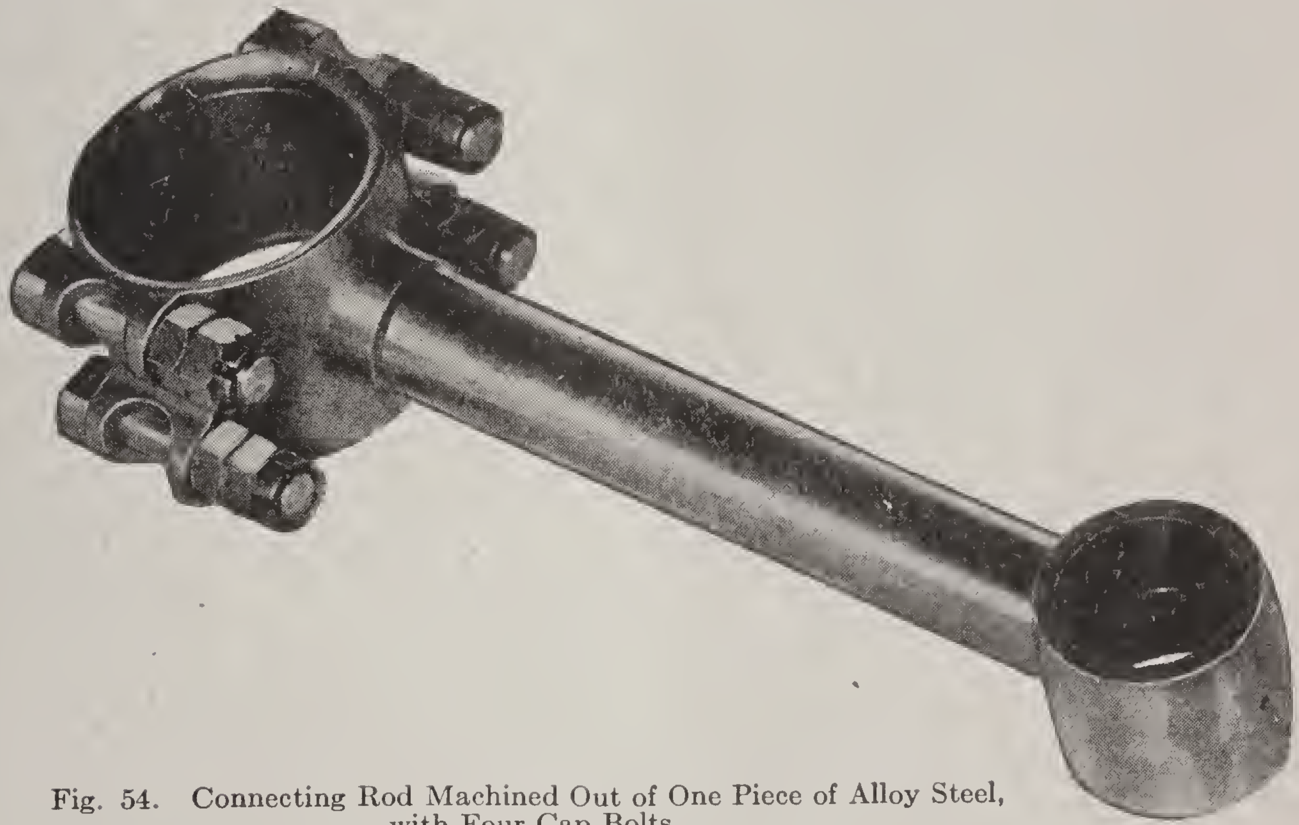


Fig. 54. Connecting Rod Machined Out of One Piece of Alloy Steel, with Four Cap Bolts

Fig. 54 shows an example of a very light-weight, high-quality, aviation-motor connecting rod, machined out of a solid bar of alloy steel, and provided with four bolts in the cap.

Connecting-Rod Bearings. *Usual Types.* Connecting rods have two different forms of bearings. This is due to the difference in their service. At the upper or piston end, the bearing is usually a high-grade bronze tubing, machined all over and pressed in place. When in place, it generally has a central oil hole drilled through rod and bushing, and then a couple of oil grooves are scraped in by hand to start from this hole and distribute the oil outward in both directions on its inner surface.

At the lower or, as it is usually called, big end, the connecting rod must have a better bearing. This end is bolted around the crankshaft pin and must sustain high rubbing speed, as well as the load of explosions. Bolting it on, and the need for removing it occasionally, call for a form which is split horizontally. Generally, this bearing is of high-grade bronze with a softer, or babbitt, central lining which can be replaced easily and quickly. The harder bronze back will sustain the stresses of bolting up tight and stand up under the constant pounding, while the softer and renewable center takes all ordinary wear. These bearings are fitted with great care. They are reamed by hand after machining, and then hand scraped to a precise fit. They are pinned in place, drilled for oil, and grooved to distribute it.

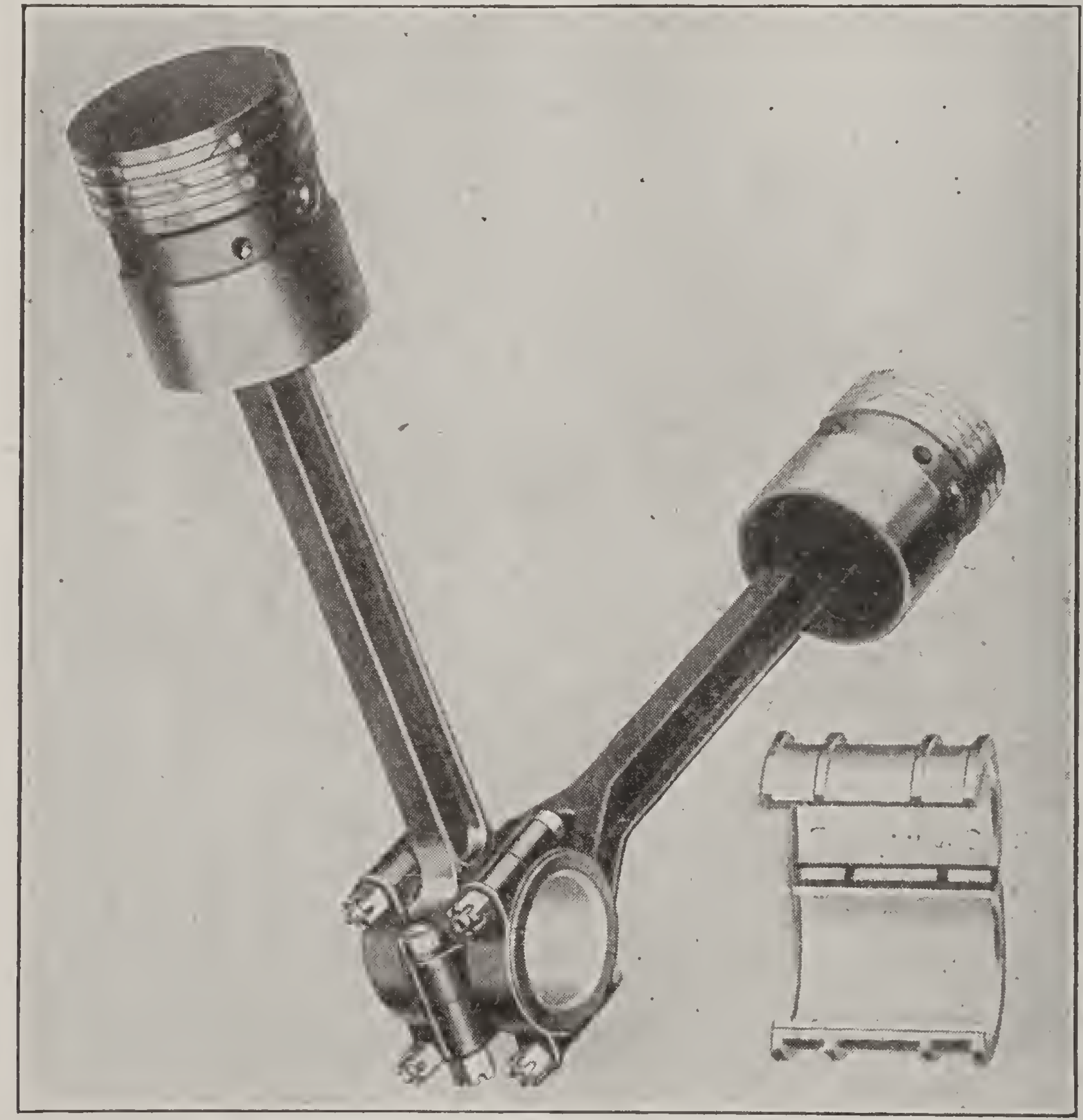


Fig. 55. Connecting Rods for V-Type Engine, Showing Method of Forking One Rod
Courtesy of Cadillac Motor Car Company, Detroit, Michigan

Eight- and Twelve-V-Types. The eight- and twelve-cylinder V-type motors have altered the design of connecting-rod bearings somewhat, in that there are two connecting-rod big ends working upon one crank pin, that is, an eight-cylinder V-engine uses a four-cylinder form of crankshaft with two connecting rods on each pin. This modifies what was good connecting rod bearing practice, one of two different forms being utilized. When the rods are placed side by side with individual bearings, the pins are made very large and as long as possible, in order to give adequate bearing surface. The other form is the forked rod in which one rod works within a slot in the other. In this type, a split bearing of the usual form is placed in the forked or long rod, and the outer surface of the central part of this prepared as a pin surface for the other or central rod. The requisite area of the smaller rod bearing is made up by its larger diameter. This is well shown in Fig. 55, where the rods and bearing are shown assembled, and the separate big-end bearing is shown at the right. In another type of V-motor connecting-rod bearing, the larger bearing is slotted for the central rod and its bearing, the slot being made large enough to permit a rotation, which never exceeds a quarter of a turn. This arrangement is more complicated to install and repair than the form shown.

Connecting Rod Troubles and Repairs

Classification of Troubles. In general, all connecting-rod troubles come under one of four headings: straight rod, proper bearing adjustment, mechanical work (scraping bearings, straightening rod, or other work), and special equipment for doing connecting-rod work.

Straightening Bent Rod. The need for a straight and true rod is apparent, but it is surprising how many rods are not straight, particularly in old motors. Many erratic and bad-sounding motors, have all their trouble caused by a bent rod. A connecting rod can be bent either of two ways, and one gives as much trouble as the other. If bent in the plane of rotation, the rod will simply be shortened, the piston will not go as high as it should, and it will go down a little lower than normal. Moreover, the bend will press it with unusual force on the cylinder wall on one side and cause it to wear more than the other.

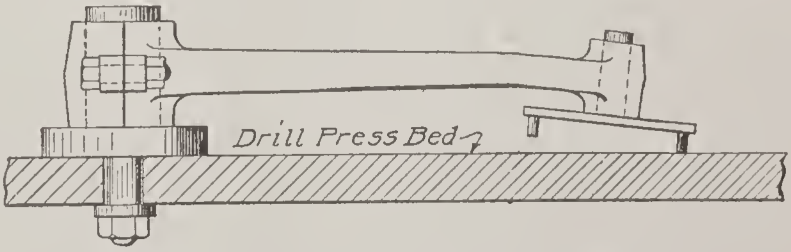


Fig. 56. Method of Testing Connecting Rods with Two Mandrels

The combination will soon result in trouble. When bent in a longitudinal direction, that is, fore and aft, the upper end of the rod will run against one side of the piston or perhaps only knock against it on each stroke. At any rate, this too, will give trouble.

Methods of Testing Straightness of Rods. The first thing to do when a connecting rod is suspected is to take it out and test it. One way of doing this is to attach the lower end to a mandrel, which can be bolted into a drill-press table, as shown in Fig. 56. Before doing this, the small end is also fitted with a mandrel, the lower part of which is of considerable length and has two short vertical pegs. When the big end is bolted down, if both the small pegs on the other end touch, it proves at least that the two holes (big end and small end) are parallel. If one of these pegs is off the table as shown, it proves that the two holes are not parallel. In the latter case, the rod would need to be straightened, as nothing but the bending of the rod would throw the holes out of parallel when they were bored correctly.

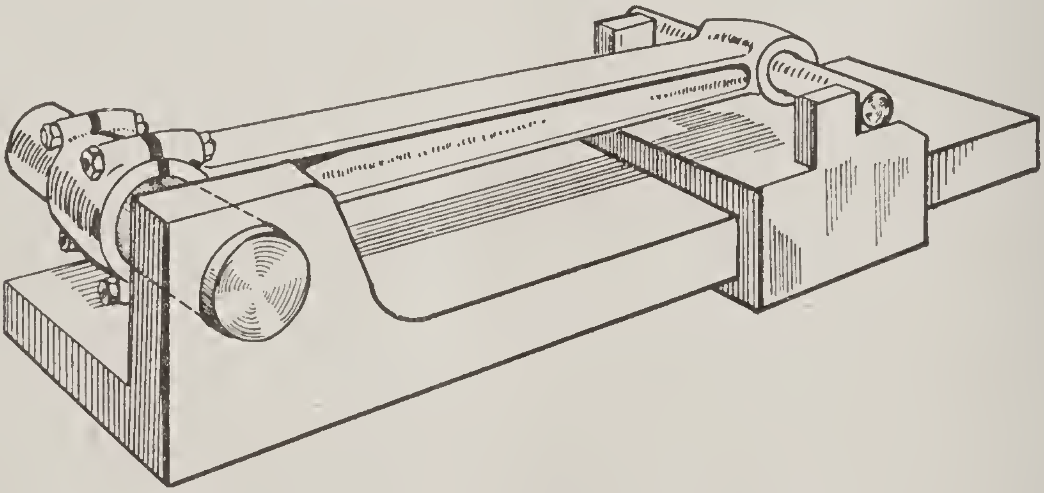


Fig. 57. Complete Connecting-Rod Testing Fixture

Another method, which is very similar, consists in forcing two mandrels of equal length into the two holes, until each is centered in the rod. Then, if the rod be placed on supports on the surface plate, or other similar true surface, so that one mandrel is horizontal, the surface gage will show at once if the other end is also horizontal, and thus, if the rod is straight and true. It will also show how much it is twisted, if out of true. If the mandrels are made long enough, ordinary calipers can be substituted for the surface gage with equally accurate results.

A method almost the same as that just described is utilized in the testing fixture shown in Fig. 57. The advantage of such a fixture is that it always works the same, while the use of surface gages and calipers varies from one workman to another, and even with the same man, from day to day, according to his moods and feelings. As the sketch shows, there is a mandrel for each end of the rod, that for the big end being pivoted in the fixture. When the rod is forced into this, and the other mandrel put in place in the piston end, if rotated down to a flat position (as shown), the small end mandrel should touch both of the fixture stops. If badly twisted, it will not be able to go down on one side.

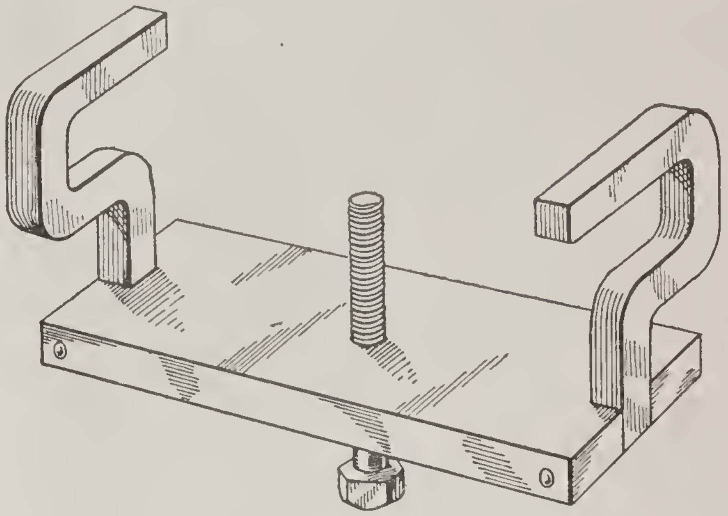


Fig. 58. Connecting-Rod Straightener Constructed from Three-Quarter-Inch Bar Stock

Straightening Jigs. When it has been proved that the rod is not straight, it is necessary to have a device for applying pressure in order to straighten it. The simplest way is an ordinary straightening press consisting of a pair of ways with V-blocks upon which the work is supported and a lever or screw to apply the pressure in the middle. The work is supported on the V-blocks, the distance apart varying with the amount it is to be bent—far apart for a big bend, close together for a small one. For as short a member as a connecting rod, however, this is not sufficiently accurate, and besides, the form of the rod does not suit it to good results by this method.

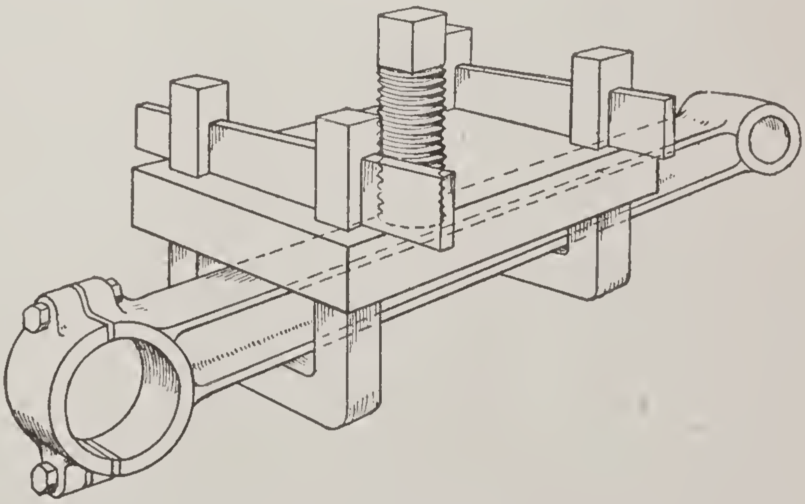


Fig. 59. Box Type of Connecting-Rod Straightener

A simple fixture for bending a rod, shown in Fig. 58, consists of a pair of hooks for holding it and a central screw for applying power. The rod is slid into place inside the hooks and the screw turned until the rod is straightened. Then to prevent its springing back when the pressure is released, it is peened on the side opposite the screw. The advantage of this method is that it throws all stresses upon the rod itself and none on the bearing surfaces. The hooks are forged from high-carbon steel of $\frac{3}{4}$-inch square section. The screw should be not less than $\frac{5}{8}$ inch to $\frac{3}{4}$ inch in diameter and fine threaded.

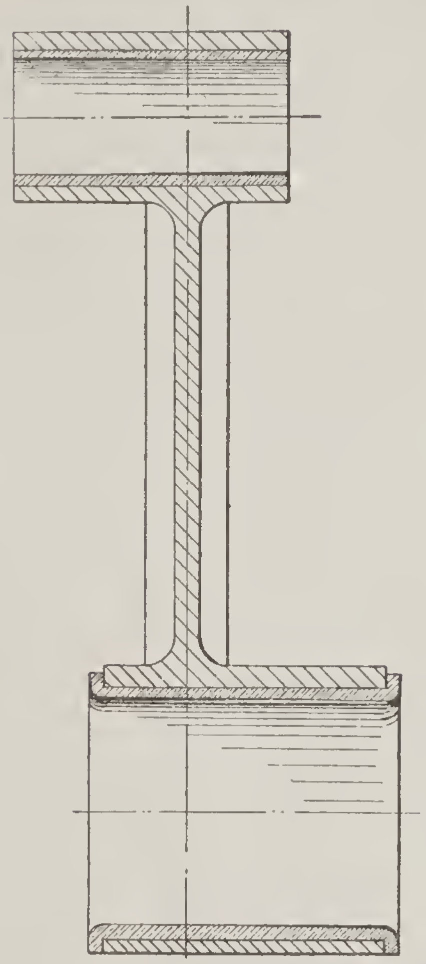


Fig. 60. Offset Connecting Rod Showing How Bearings Wear

Another fixture is on the box order, shown in Fig. 59. This has a pair of end clips which hold the rod tight by means of wedges which are driven into place. When this has been done, the rod is straightened by means of the central screw. As will be noted, the principal difference between the two forms, Figs. 58 and 59, is in the holding method. There are other forms, as well as forms of mandrels for lapping in big-end bearings, which are so constructed as to give a check on straightness and to allow of remedying the situation if the rod is not straight. Some of these will be described.

Offsetting Causes Trouble. Many motors are built with offset connecting rods, that is, the application of pressure on the upper end is not upon the center line of the bottom end. This is exaggerated in Fig. 60, which indicates also how this situation causes wear on the upper left end and lower right end of both bearings. The sketch also shows how this unequal wear is greater on the crank end, which is offset, than upon the piston end. The cause of this wear is simple, the pressure is unbalanced on the left side, so a downward push on that side is taken up by extra wear there, and on an upward push, as on the compression stroke when the flywheel is driving the pistons, the extra resistance of the left side causes unusual upward pressure on the right side. So the ends continue to wear, until

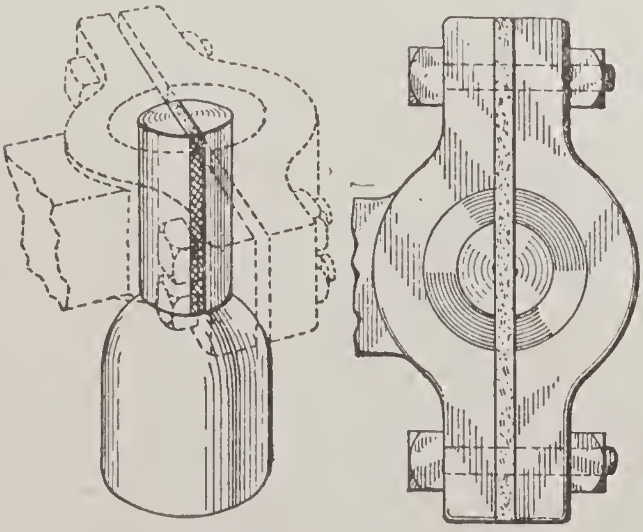


Fig. 61. Wooden Core for Babbitting Connecting-Rod Bearings

a rocking motion of the pins results, and this causes a noise. New bearings help temporarily, but a stiffer connecting rod will often remedy it more or less permanently.

Adjustment of Connecting-Rod Bearings. *Babbitting Bearings.* As has been stated, the majority of connecting-rod and crankshaft bearings are bronze shells or backs, lined or faced with babbitt as a wearing metal. The bronze provides the stiffness and long life, the babbitt, the softer wearing face which is easily and cheaply replaced. In this replacement, a form or jig to simulate the crankpin and approximate its size must be used for a center. A form made of wood is shown in Fig. 61. This is simply a round member of hard wood, turned up slightly smaller than the actual crankpin at the upper end, while the lower end is left large to form an under surface for the metal. Next, the upper part is split or rather has a cut taken across it, equal in thickness to the shim to be used when the bearing is assembled in place. Then, when the babbitt is poured in, a metal member is set across the rod to form the shim, which is shown in the smaller sketch at the right.

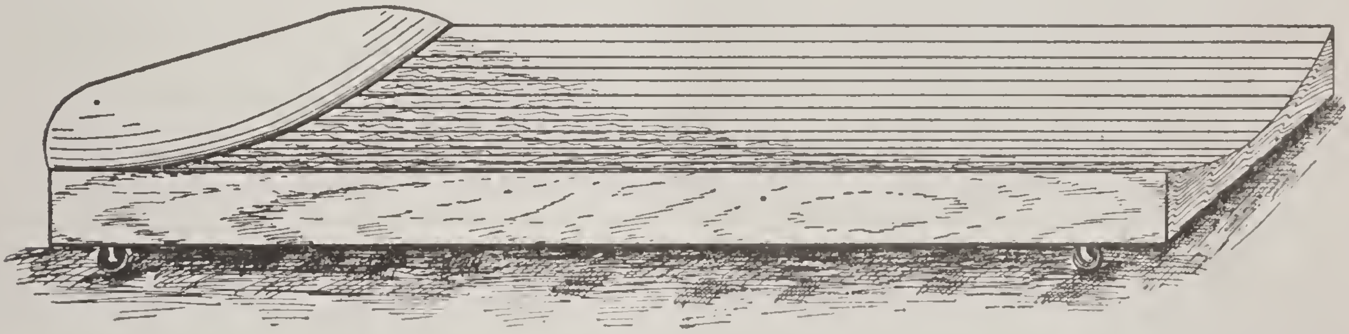


Fig. 62. Home-Made Creeper

This method has the advantage over that of using the pin when pouring the metal in position, because it gives a little surplus to machine off, and thus makes the surface more accurate before it is scraped. If broaching to harden the surface of the metal is resorted to, it gives a little metal to broach down. Moreover, by making it so simple and easy to handle, the work of babbitting is made easy. This cannot be said of trying to babbitt in place. The core need not necessarily be of wood; it can be of metal or of anything else desired. But the wood has the advantage of being easily worked, or of being cheap and quickly obtained.

Kinks in Adjusting Bearings. Usually, crankshaft and connecting-rod bearing adjustment is a difficult job. This is particularly true when the engine is not removed from the chassis. The connecting-rod bolts are tight and hard to reach, and the operator, who is lying on his back, has all dislodged dirt or oil dropping in his face. Work like this calls for an easy means of getting under the engine and out again. For this, a form of creeper is necessary. There are many forms made and sold, but a simple one which any repair man can construct for himself is shown in Fig. 62. This consists of a wood frame with casters at the four corners and longitudinal slats for the floor. By making the ends concave, the surface is made concave. With a pillow or other head rest, it is more comfortable to use.

Another way in which this work may be facilitated is to make a special socket wrench for connecting-rod nuts and to make it deep enough to hold four nuts, one over the other. Then with a spring-stop arrangement, Fig. 63, the nuts from two rods can be taken off without stopping; or if lock nuts are used, the nuts and lock nuts may be removed from one rod. This is accomplished by means of four spring-operated pins. When the first nut is removed, it sticks in the end of the tool, but pushing this into the second one moves the first nut on up inside the socket. In replacement, when the upper pins are pulled, a nut drops down and is held by the lower pins enough to start it on the bolt end. When tightened, the socket can be pulled off, and the next nut dropped down and fixed in place by hand. The four pins have hardened ends, and the springs are old clock springs to which the upper pair of pins are brazed. The lower pins can be free. This form of socket wrench can be used with equal advantage in many other inaccessible places. Its single drawback is that it can only be of one size; and a set of them have to be constructed to take care of all needs.

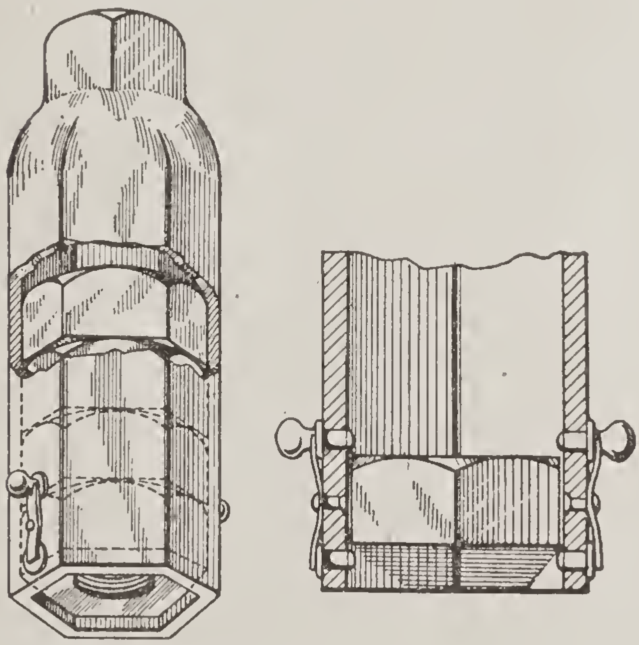


Fig. 63. Spring Clips on Socket Wrench for Use in Inaccessible Places

In ordinary bearing adjustment, the nuts are taken off, the connecting-rod cap removed, and the shims taken out; say, a shim of .001-inch thickness for very small wear, .002 inch for considerable wear, and .003 inch for severe wear. If more than this has been worn off the bearings, they need re-scraping, as this is about the maximum that can be taken out without scraping. Usually, when

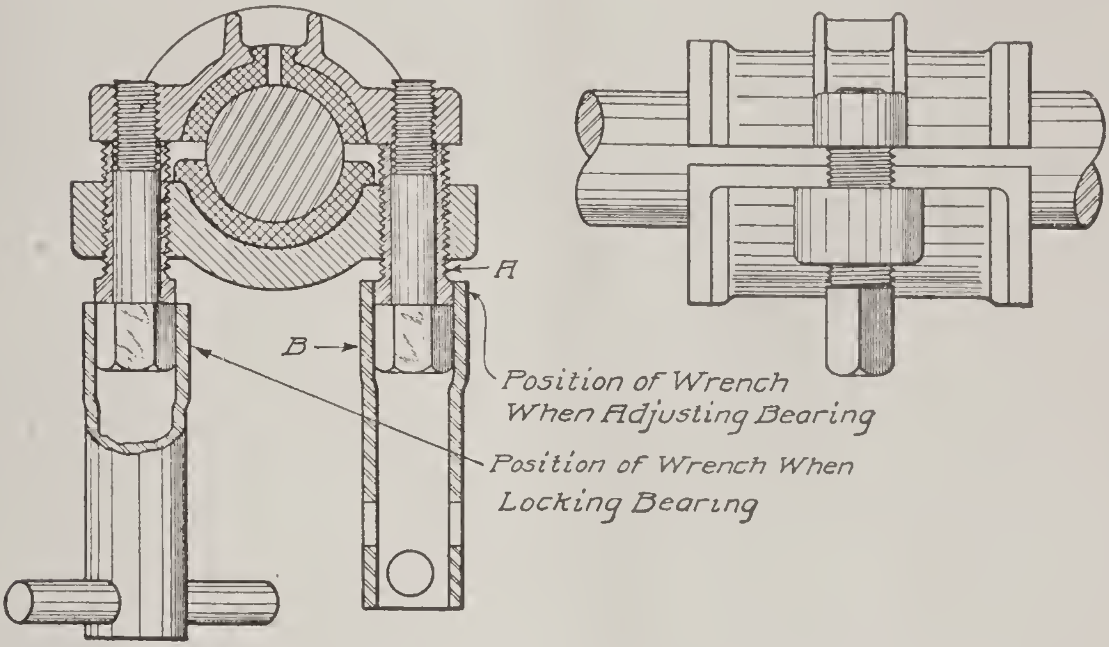

A
B
Position of Wrench When Adjusting Bearing
Position of Wrench When Locking Bearing

Fig. 64. Connecting Rod and Main Bearings Constructed without Shims
Courtesy of Reo Motor Car Company, Lansing, Michigan

the bearings have been taken up in this way, the caps are put back on pretty tight, a little bit tighter than they were previously. Then they are flooded with oil and run in this condition. The combination of excess oil and tight caps soon gives the entire bearing surface a fine polish which will last for many miles.

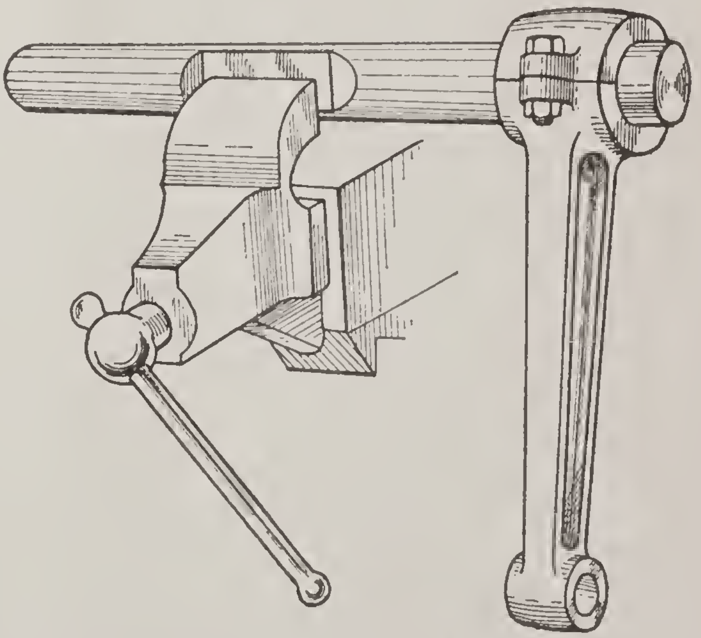


Fig. 65. Standard Mandrel Method of Lapping Big-End Bearings of Connecting Rods

Special Sleeve Replaces Shims. In one motor (Reo), the shim is replaced by an ingenious arrangement of a threaded sleeve around the bearing bolts. This is shown in Fig. 64 in which the sleeves are marked *A* and the bolts *B*. It will be noted that the sleeves rest against the upper part of the bearing and have a head against which the bolts rest, so that the latter can be tightened only as far as the sleeves allow. With this construction, when it is desired to tighten a bearing, the socket wrench is slid on so as to hold the heads of both bolt and sleeve, and then turned to unscrew both.

Then the socket is drawn off the sleeve head, in the position shown at the left, and the bolt screwed back to pinch the bearing together and lock it. As will be noted, the two halves of the bearing metal are separated a considerable distance so that this arrangement is good for many thousand miles. Two years' running will usually exhaust the possibilities of the original bearing and its shims, which calls for re-babbitting, re-scraping, new shims, or for an entirely new bearing. This form of construction could be used anywhere that the bearings are likely to need frequent readjustment.

Mandrel for Lapping. In order to give the connecting-rod bearings the best possible surface, a mandrel should be used to lap them in. This is the equivalent of running in. The rod, with bearings in place, is put on the mandrel, and the bolts tightened a little; then it is worked back and forth, until the flattening down of the surface will allow more tightening of the bolts. This is continued until, with a mandrel the exact size of the crankpins, the bolts can be pulled up dead tight. Then the rod is removed; it is finished. Such a mandrel, shown in Fig. 65, is usually a piece of steel turned up on one end to the exact size of the crankpin, with a flat spot machined in the other end to allow holding in the vice. By making it perfectly straight, a try square against the mandrel will show the correctness of the rod. On the other hand, if the outer end be made with a very slight taper, it is easier to work the rod on and off and easier to inspect the inside surface without unbolting.

Drilling Thin Shims. When thin brass shims are used, and the shape is formed by the workman, it is difficult to get a good true hole because of the extreme thinness of the metal. By collecting a number of these together and clamping them between two blocks of wood, a straight true hole can be bored through wood and brass with an ordinary bit and brace. The use of laminated shims avoids all this, as they come in the required thickness and are drilled to size. With these, adjustment is simply a matter of peeling off one of the laminations.

CRANKSHAFTS

Material. The crankshaft in all but heavy slow-running motors should be made of the finest alloy steel obtainable, for it carries the practical equivalent of thousands upon thousands of heavy blows.

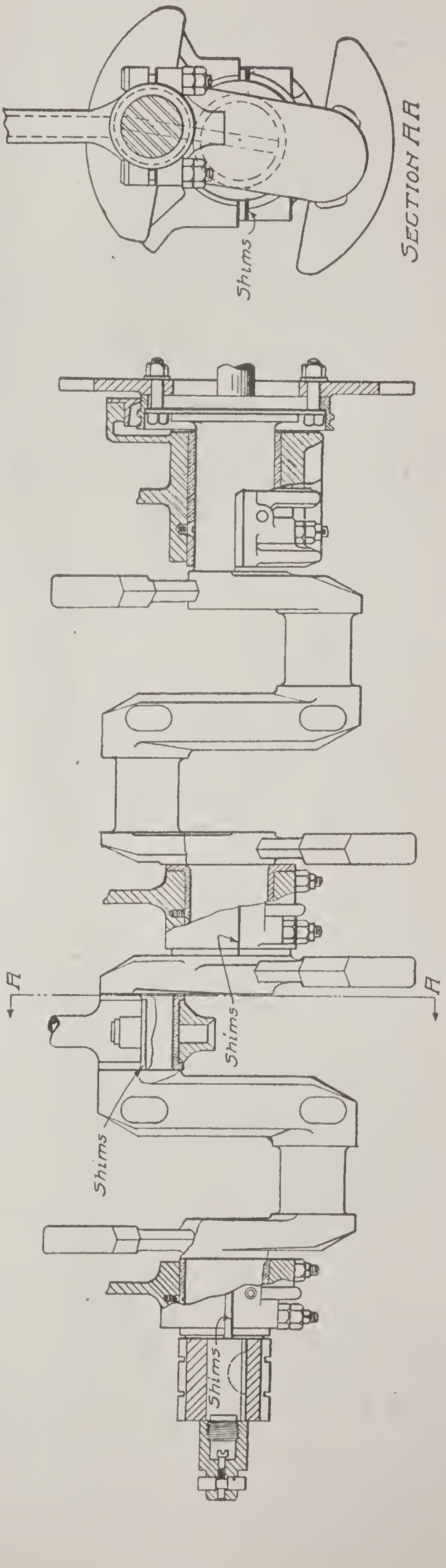


Fig. 66. Four-Cylinder Three-Bearing Balanced Crankshaft
Courtesy of F. B Stearns Company, Cleveland, Ohio

Variation of Design. The greatest variations in automobile crankshaft design, aside from those permitted or made necessary by differences in the quality of material, are due to the conditions involved in the different combinations of cylinders that can be utilized. Thus the number of crank throws, as well as their position, varies with the type of motor.

As the repair man knows crankshafts today, they are of two kinds. The first is the four-cylinder form, in which all throws are in a single plane. This type of shaft has four pins, one for each connecting-rod big-end bearing. It may have either three bearings, as shown in Fig. 66, or five bearings. The second type, which the repair man is likely to meet, is the six-cylinder shaft, which will have six pins for connecting rods; these are grouped in pairs, and each pair in a different plane, the angle between them being 120 degrees. This type of shaft may have either four or seven bearings. In the four-bearing form, there is a bearing at each end, and another between each pair of cylinders, as shown in Fig. 67, with pistons and connecting rods attached. In the seven-bearing form, there is a bearing on each side of each connecting rod. These are the modern types, but older shafts may be encountered occasionally, in the way of four-cylinder shafts with two bearings, one at each end only; also with four bearings, the latter having the usual center bearing eliminated. The modern tendency is toward simplification, compactness, and lowered first cost; and the shafts with the fewer number of bearings are on the increase.

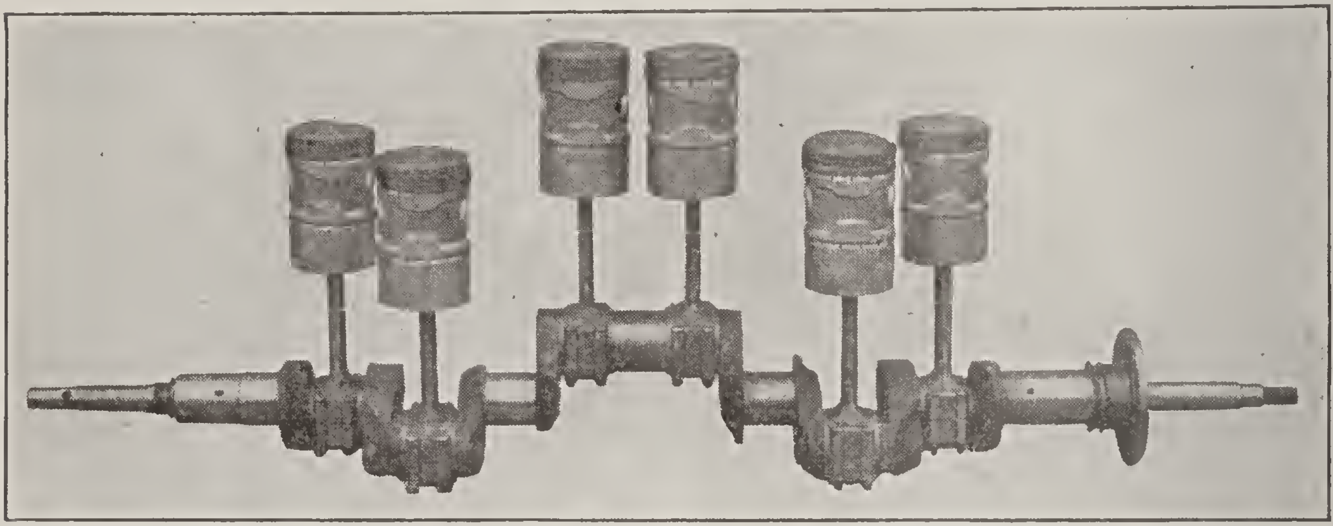


Fig. 67. Six-Cylinder Four-Bearing Crankshaft with Pistons and Connecting Rods Assembled
Courtesy of Nordyke & Marmon Company, Indianapolis, Indiana

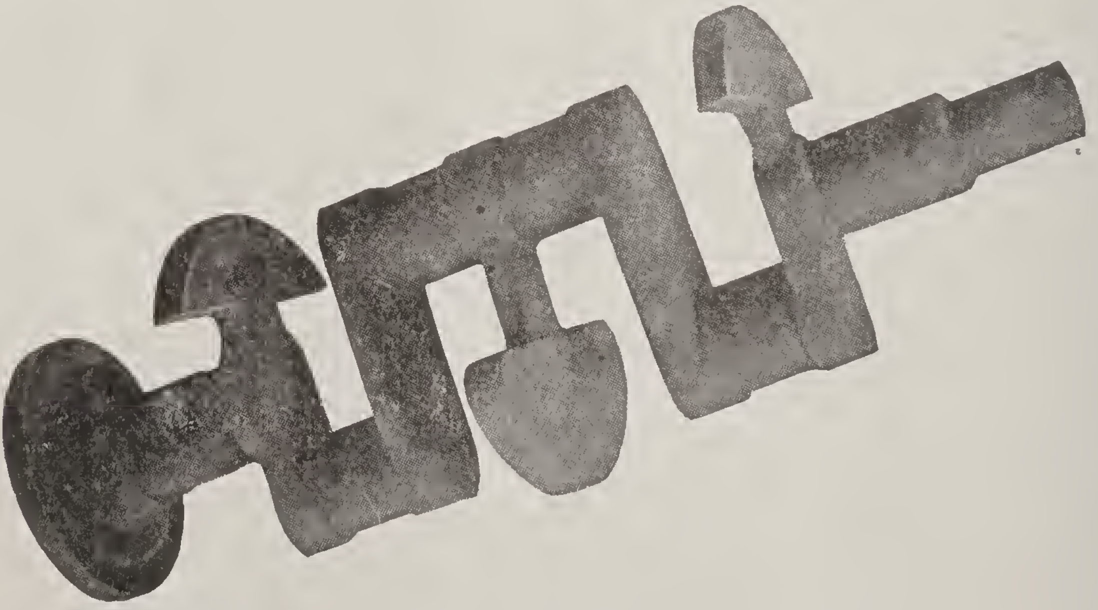


Fig. 68. Typical Drop-Forged-Balanced Crankshaft
Courtesy of Park Drop Forge Company, Cleveland, Ohio

Crankshafts may be found which are drilled out for lubricant passages. In such cases, the repair man must look for attachments which feed the oil into the hollow interior. Also, he may meet a ball-bearing form of shaft which has been built up to allow the bearings to be assembled. Such a shaft should be handled with extreme care.

Eight-cylinder engines generally use a four-cylinder form of shaft, with two connecting rods on each of the four pins. This is explained previously under connecting rods. Similarly, twelve-cylinder motors have a typical six-cylinder crankshaft, with two rods on each of the six pins.

Balanced Crankshafts. While not an assembled shaft in the sense just referred to, the balanced form is meeting with great favor, and is being widely adopted. This will be met by the repair man in two forms. One is like Fig. 66, except that the weights are machined to fit on the crank cheeks and bolted there. The repair man should not remove these unless it is absolutely necessary, as they vary in size and weight. They are fitted in place with extreme care and fastened extremely well. The other type—the kind being introduced into the latest models—has its counterweights forged as a part of the crankshaft, Fig. 68. In this type, the weights are adjusted to make the proper balance when the shaft is being machined.

Crankshaft Bearings. The bearings of the crankshaft in the crankcase do not differ materially from the connecting-rod bearings just shown and described. They may be a little longer, but the type is the same. They are pinned or otherwise fastened in the crankcase so as not to rotate, while the connecting-rod bearings are fastened in the connecting rods so as to rotate with them. A few shafts will be met which have ball or roller bearings, but the great majority have the split bronze-backed, babbitt-faced bearing described for connecting rods.

Crankshaft and Connecting-Rod Bearing Shims. Practically all split or two-piece bearings for either crankshafts or connecting rods are assembled in place with shims. These are very thin flat pieces of metal set between the two halves of the bearing when it is assembled new to spread it apart. The shaft bearings are scraped to an exact fit on the pins with these shims or expanders in place. Then when wear occurs in the bearing, so that its inside diameter is enlarged, the bolts may be taken out, a shim or shims of the required thickness removed, and the bolts put back and tightened. This removal reduces the diameter of the inside of the bearing. To facilitate this action, the shims are generally put in, in such a way as to allow taking out a number of thousandths of an inch, there being two shims of $\frac{1}{1000}$, two or more of $\frac{2}{1000}$, possibly one of $\frac{5}{1000}$, and a thicker one, or more of the very thin ones. These shims enable the taking-up of wear amounting to $\frac{1}{1000}$ of an inch, when one of the thinnest shims is removed; $\frac{2}{1000}$ by removing one of that thickness; $\frac{3}{1000}$ by removing a $\frac{1}{1000}$ and a $\frac{2}{1000}$; $\frac{4}{1000}$ by taking two 2's, etc.

Of course, a crankshaft bearing or a connecting rod-bearing will not wear entirely round, but the work of adjusting either bearing is reduced to a minimum by the use of shims. When the wear is very bad, the bearings should be re-fitted and the shims left out.

An entirely new form is the laminated shim. The total thickness required is built up of very thin laminations, either one or two thousandths of an inch thick, so that in adjusting a bearing as many laminations are peeled off as are necessary to take up the wear, then the original shim, slightly lessened in thickness is replaced.

In Fig. 66, the end view shows both connecting-rod and crankshaft bearing shims in place, and indicates how they perform their function of holding the halves of the bearing apart when the bearing is being fitted.

Crankshaft and Bearing Troubles, and Remedies

Bearings. Bearings of the two-piece, or split, type give the auto repair man fully as much trouble as anything, in fact, the crankshaft bearings should not be tackled until considerable repair experience has been had. In general, wear on the bearings is due to one of two causes: either to a soft metal which has caused vertical wear on the inside or outside of the lower half of the bushing, or to a vibrating shaft which has worn an oval hole somewhere in the length of the shaft, as at the inner or outer end.

In the former case, the height of the worn half must be reduced. This is usually done by taking as much metal from the upper face as is necessary. When this has been done—either by filing or by rubbing across emery cloth wet with oil—the two halves of the bushing will approach so close together that the hole will be smaller than the shaft. This will necessitate scraping out, or reboring, according to the amount which has been taken off. In the case of very small amounts, this wear can be taken up by removing shims, as mentioned above.

When the second form of wear is found, that is, when the bushing is worn oval by a wobbling shaft end, the only remedy is to bring the bearing halves together as before and re-bore. It may be that this operation robs the bearing plates of so much metal that they will not fit the holes in the case; or possibly the wear may have communicated itself to the case, so that the hole there is out of true. If this be slight, refilling the cases with babbitt metal or building-up may be resorted to, but if the wear is considerable, a new set of bearings is the only remedy. In building up the bearing, strips of soft metal are placed in the worn spots, after cutting or filing them to fit as closely as possible, and the bearing driven down upon them as firmly as possible. In this way, it is often possible to build up a worn crankcase to answer for many thousand more miles running.

Bearing Wear. In this connection, it is important to know how and why bearings wear. Normally, between the crankshaft bearing and the pin, there is a space of perhaps .002 inch divided into .001 inch all around, and this space is occupied by a film of lubricant. So long as this is the case, if the metal remains hard and does not give under the constant pounding, and the film of lubricant stays unbroken, it remains a perfect bearing. But the film does get broken or reduced, and the softer metal does give, so we have a condition shown at *A*, Fig. 69. Instead of a cylindrical pin centered in a cylindrical hole, one or the other is worn oval. This is usually the bearing, for the weight of the

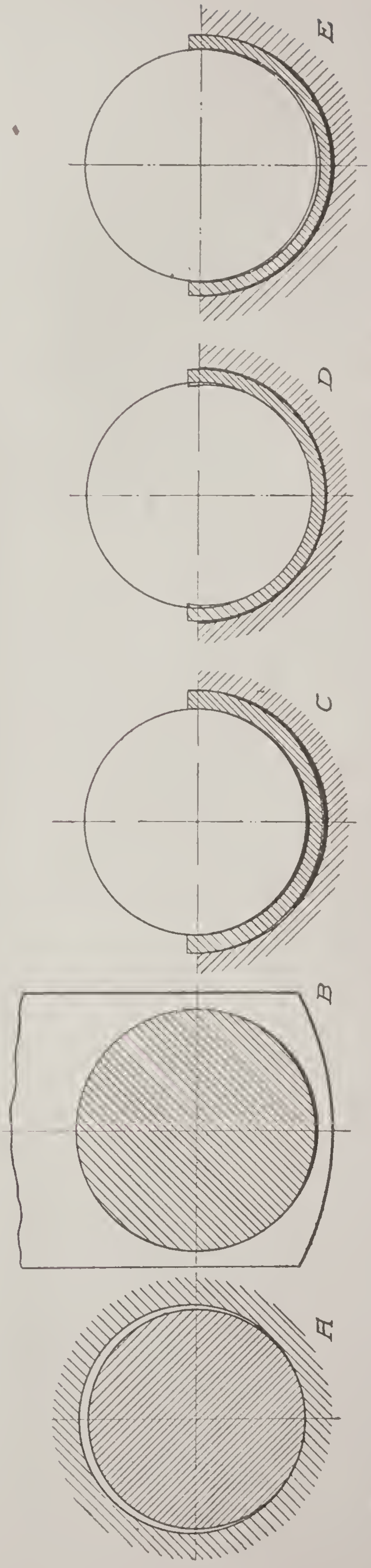


Fig. 69. Wear in Crankshaft Bearings. *A*—Section through Worn Bearings; *B*—Flat Spot on Shaft; *C*—Incorrectly Fitted Shim; *D*—Bearing at *C* Fitted by Scraping Bearing and Case; *E*—Bearing at *C* Fitted by Scraping Shim only

shaft, coupled with the pressure on it, keeps it at the bottom of the hole. The tendency, then, is to increase this eccentricity. In this condition, the pin is running against the bearing metal at only one very limited surface, so all the pressure and all the wear are concentrated there. If the bearing is hard, or if a hard spot develops, the pin is likely to wear flat on the bottom side, as shown at *B*. When the bearing is fitted to the case, great care and accuracy are required. If care is not taken, an incorrect fitting, shown at *C*, results. Here the shim does not entirely fill the opening for it, and the bearing metal rests on the case at one point; on the shim at another; and does not touch either at a third. This is remedied by scraping both bearing and case, as shown at *D*, or the shim alone as seen at *E*. In the former it will be noted how the full shim has raised the bearing so that its points project into the pin, where scraping will be needed. In the latter case, also, scraping the bottom of the bearing will be necessary, for using a fully fitted shim has raised the center more than the sides.

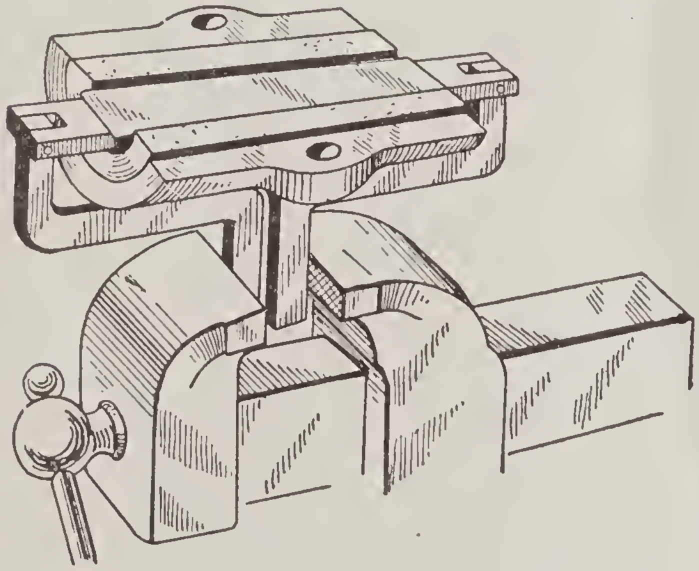


Fig. 70. Holding Fixture for Crankshaft Bearing Caps

Crankshaft Pounding. When the dull throbbing noise is found to come from within the crankcase, possibly between two of the bearings, this indicates a crankshaft or a connecting-rod pound. That is to say, either the rod is loose on the shaft or the shaft is loose in one of its bearings. Whenever the force of an explosion comes on the piston and drives it down, this looseness is taken up quickly, and the dull pounding noise is made. This is a serious trouble and, if long continued, may wreck the engine. That is, the loose rod may become entirely loose and free so as to thrash around and, in so doing, wreck the crankcase; or, if the pound comes from the shaft, the bearing may continue to loosen and finally that part of the shaft become entirely free to thrash around. Both these troubles can be overcome by tightening of the bearing caps.

Test for Tightness. When a connecting rod has been fitted to a crankpin and is ready for use, a simple test of correct tightness is this: If the rod is placed vertical, it will stay there, but if pulled over past 20 degrees from a vertical, it will swing down, of itself, to the bottom position and stop there without continuing to swing. If it will do this, it is just tight enough. If it will not swing down at all or continues swinging, it is either too tight or too loose. To a certain extent, crankshaft bearings are delicate, and they can be ruined by having the big ends too tight.

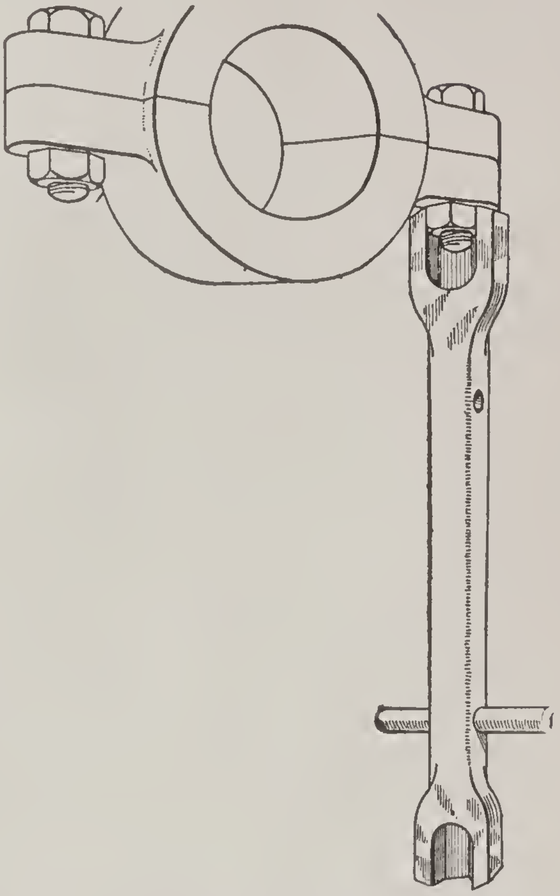


Fig. 71. Semi-Socket Wrench for Crankshaft Bearing Nuts

Holder for Bearing Caps. When a number of bearing caps have to be scraped, or filed down, it is worth while to make a holder for them. A plain form is shown in Fig. 70. This consists of a semicircular piece of metal which fits into the hollow part of the bearing, with each end pivoted on two L-shaped members. The members are held tightly in the vise, and the tighter they are gripped the tighter the bearing cap is held. This jig holds the cap with the desired firmness, yet it leaves the whole upper surface free and clear so the workman can work at it readily and do a neat quick job of filing.

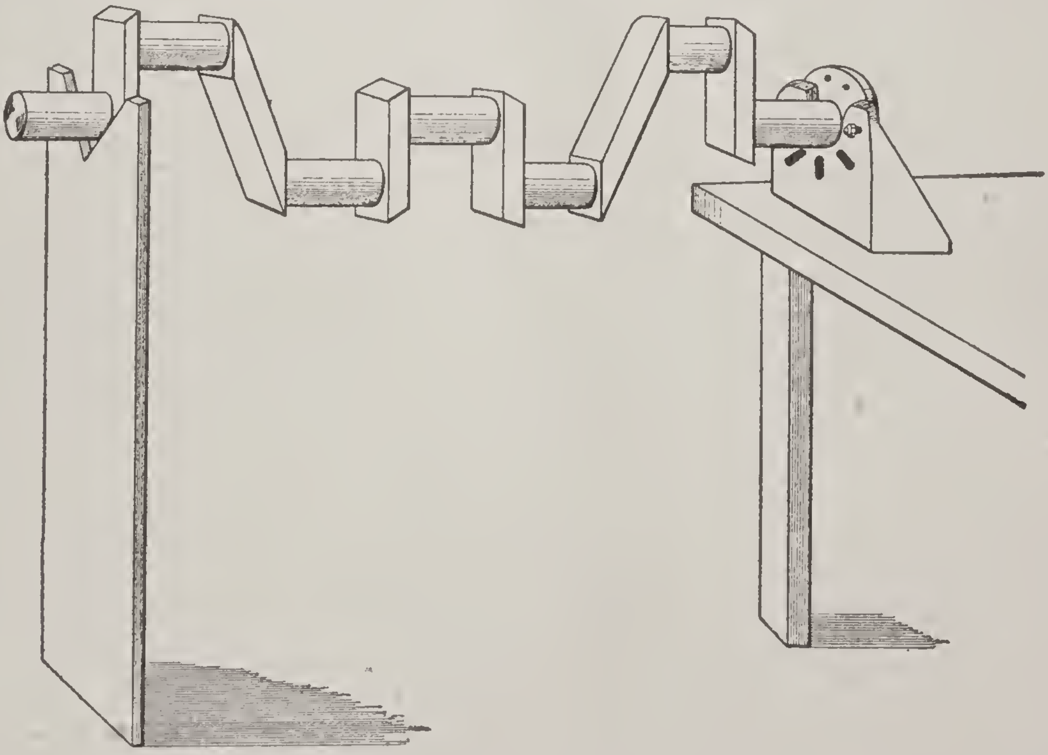


Fig. 72. Set-Up for Supporting Crankshafts Out of Motor

The same layout is suitable for connecting-rod caps, except where they have an oil scoop or other central projection which interferes.

Another Handy Wrench. The form of the crankshaft-bearing cap and also of the connecting-rod bearing cap are such that no space is wasted. Very often the nut is so close to the cap that it is difficult to turn, unless the cap is taken out of the motor where the wrench can be applied at right angles. The use of the socket form of wrench, however, does not make it necessary to take the cap out of the motor. Aside from the socket wrench it is hard to get any other form of wrench to use on these nuts that is not so small and thin that it has no particular strength. In Fig. 71, however, a form is shown which has all the strength of the very stiffest forms, and yet it can be applied to these inaccessible nuts with ease. Moreover, its construction is such that it can be applied and used readily. It consists, as the sketch shows, of a solid socket wrench, as distinguished from

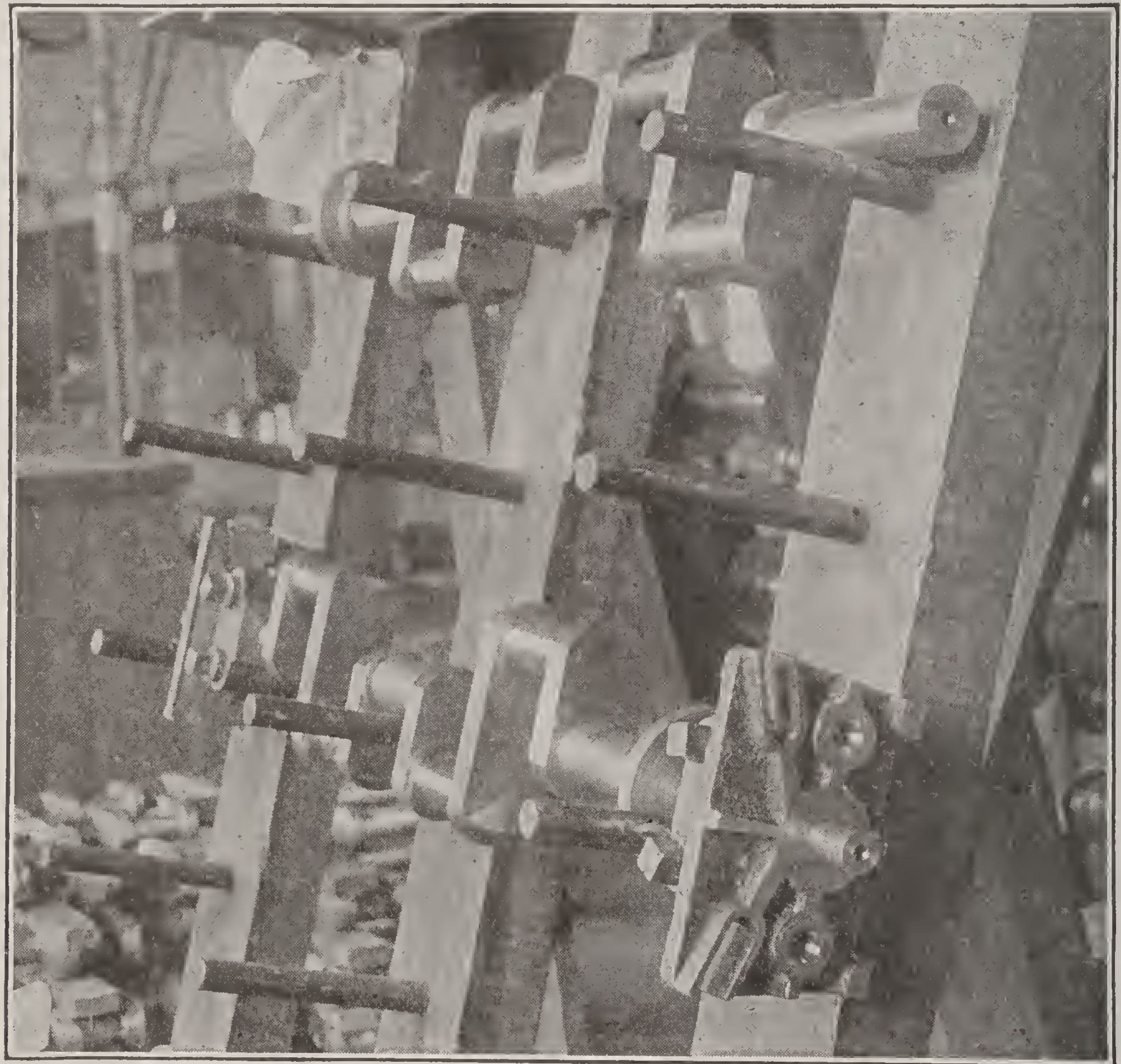


Fig. 73. Dogs for Use in Turning Four-Cylinder Crankshafts

the form made of tubing, and has part of one side of the socket cut away. This makes its quick application to the nuts easy, although it also limits the amount of turn possible. Generally the case nuts are different in size from the connecting-rod nuts; so it is advisable to make the wrench double ended with a size at one end for the rods, and one at the other end for the case.

Holding the Crankshaft. When the shaft has been removed from the engine, and work is to be done upon it, it is an awkward thing to handle. It is just delicate enough so that it cannot be handled carelessly, yet its size and weight make it difficult to move around. Thus, in lapping the shaft pins, in fitting connecting-rod bearings, or doing other work upon it, a support which is simple, easily moved around, yet adequate, is needed. Ordinarily a shaft is clamped in a vise, but this is not always satisfactory when working on an end bearing. The method shown in Fig. 72 has many advantages. This consists of a special bench fixture and a notched board. The latter should be at least 1-inch stock, that is, it should be $\frac{7}{8}$-inch when dressed on both sides. The former is simply a metal angle with a series of radial slots to take the flywheel bolts, with a central hole for the shaft to rest in. The metal above the hole is well cut away to facilitate putting the shaft in and taking it out.

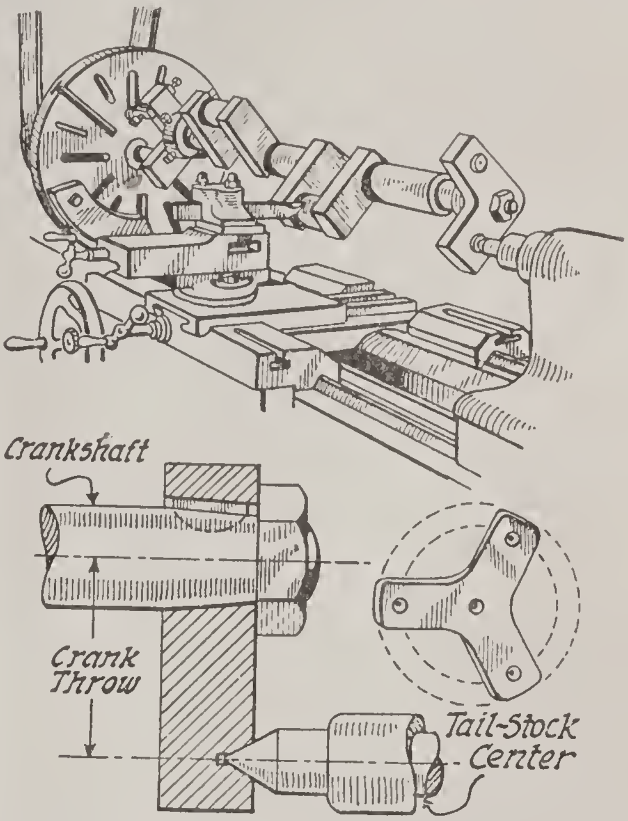


Fig. 74. Fixture and Lathe Jig for Turning Six-Cylinder Crankshafts

Handling Shaft in Machines. When the crankshaft is to be machined, no matter what the form of lathe, grinder, or other machine, the fact that the pins are eccentric necessitates a special dog or jig for holding it. If an ordinary flange is bolted on the end, the main pins can be turned, smoothed down, or ground, but the crankpins cannot. What these latter need is a form of flange or plate with two exact centers on either side of the central one at distances exactly equal to the crank throw. One is shown in Fig. 73, which is attached to a four-cylinder shaft all ready for the machine. Above will be seen another shaft without machining flanges. The bolts which attach the flanges to the shaft can be seen beyond the right-hand flange and at the far end. The rack in the background, on which these shafts are placed, is of interest also, forming, as it does, a simple and efficient means of holding the shafts, yet it is convertible for holding other parts or units. It is simply a stout form of horse, rather high, and with three legs instead of the usual two. The braces are all put on the inside to leave the surface clear, while the supporting pins differ only in length. In this case they have been made long enough and strong enough to hold two or three shafts at once. In this way, the one horse can hold some 48 shafts at once.

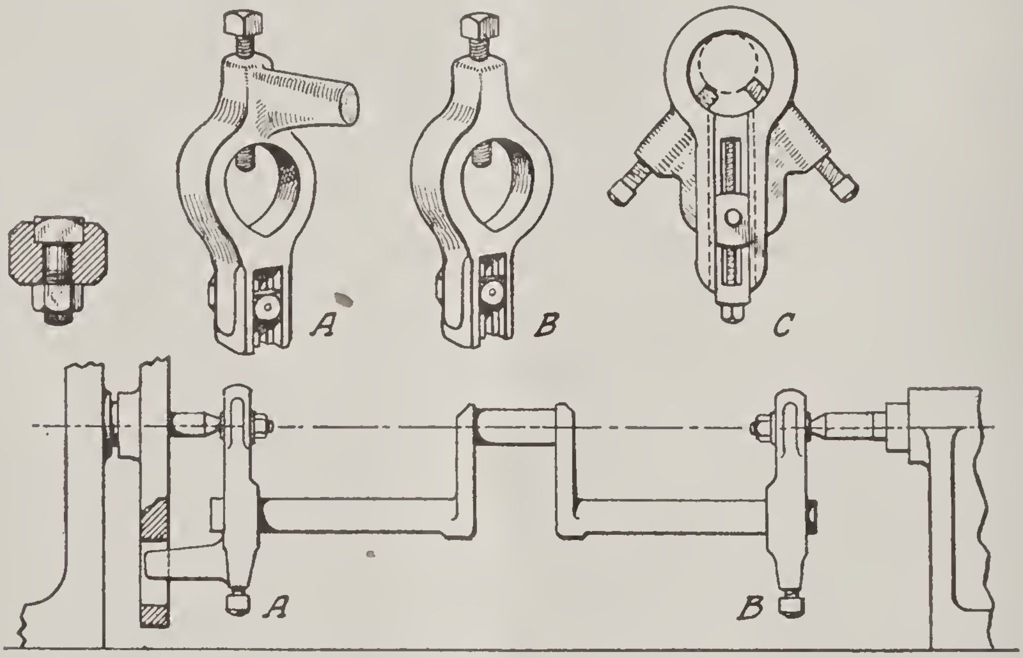


Fig. 75. Dogs with Adjustable Centers for Handling Crankshafts

Handling Three-Throw Shafts. The rigging just described is for four-cylinder shafts only, as these have the throws all in one plane, so that, although three different centers are required, they lie in one straight line, and the flange can be very simple for this reason. With a six-cylinder shaft, on the other hand, this is not the case; and a much larger flange is needed, for the three pin centers are spread out fan-like around the main bearing center. A form is shown in Fig. 74, which can be used for a shaft of this general type, although the one shown in the lathe provides for two pins only, not for three. For a six-cylinder engine of ordinary crankshaft construction, this would have to be like the triangular sketch at the lower right, if it is carried out on the same plan; or with the same bearing and pin centers, and a round outline as shown by the dotted line, if there was no necessity for saving metal.

Adjustable Crankshaft Flanges. In the small shop the general run of work varies so much that the principal difficulty lies in having flanges, dogs, or fixtures for handling the variety of crankshafts that come in. Diameters vary so much that a wide range of central holes is needed, because throws are all different. This gives a different center to center distance; then, too, there are still one- and two-throw, and other old forms of shafts in use, which come in occasionally for repairs. For these reasons, it is not wise for the small shop to go too far into special crankshaft fixtures; it should stick to simple dogs, with adjustable center distances, like the three shown in Fig. 75. While the shaft indicated is a single-cylinder form, dogs of this type can be used on other forms. This constitutes their biggest advantage. The variation in the three is self-explanatory to any machinist.

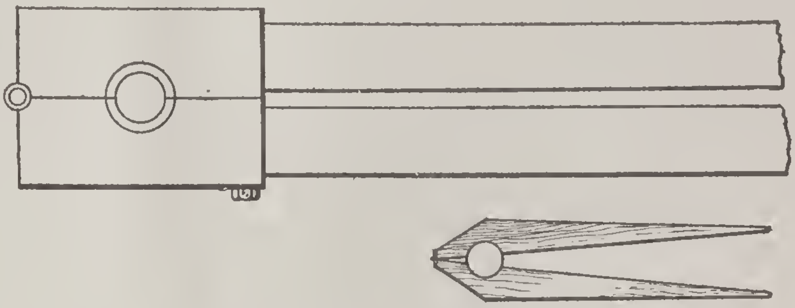


Fig. 76. Lapping Fixture of Simple Construction for Crankshaft Pins

Crankshaft Lapping. The pins of a crankshaft need lapping the same as other pins where a grinding machine is not available. There are two ways of doing this: by hand, which is slower but more simple so far as apparatus is concerned; and by machine, which requires special fittings for this purpose. In the sketch, Fig. 76, a form of hand lapper is shown. This consists of a pair of hinged members, with a central hole large enough to take various sizes of bushings, such as would be required on different shafts. A long handle is provided; also a bolt to hold the two halves together when the bushing has been inserted. The babbitt bushing must be split and have end flanges to hold the halves in place sideways. The handle gives leverage for working the tool, which is made effective by the application of fine emery and oil on the pins to be lapped. In the same way, the pins are pol-

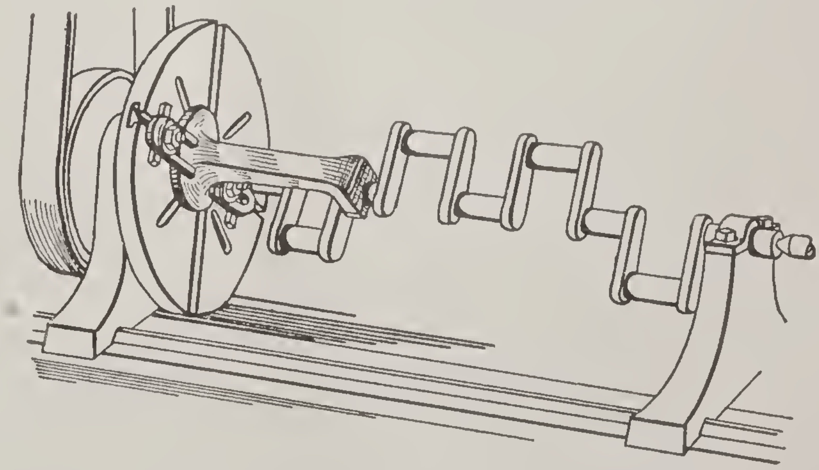


Fig. 77. Lathe Set-Up for Lapping Crankshaft Pins

ished by means of a pair of long wooden clamps, shown below, and made in somewhat the same way. There is a hinge at the back; and the abrasive used is fine emery cloth, which is flooded with oil.

The throws on the crankshaft can be lapped in the lathe by putting it between centers for the main bearings and by using a special flange for the other pins. A method which can be used is shown in Fig. 77. This consists of a special fixture, made from a large casting with a base to fasten to the face plate; a long extension arm, having a split end for attaching and detaching, to encircle the throw to be lapped. When this is used, the shaft is supported in V-blocks, somewhat flexibly it is true, but sufficiently.

Welding Shafts and Cases. The welding of broken crankshafts and crankcases, such as central breaks, breaks around the cylinder supporting surface, bearing supports, and supporting arms will be found fully discussed under the subject of welding, with full directions as to the preparation of the work, the materials, and other details.

CRANKCASES

Function of Crankcase. The lower part of the motor car, truck, or tractor engine is generally enclosed for the purpose of assisting the circulation of the lubricant, and for keeping the dirt and dust out. This enclosure is called the crankcase, and covers the crankshaft, the connecting rods, the bearings for both, and the lubricating system and lubricant reservoir. In general, the crankcase forms the support for the entire engine, as arms extend from it for this purpose. It also supports the cylinders upon its upper face or faces, and the crankshaft bearings upon inner integrally cast bosses. This is worded in this way, for formerly many marine engine cylinders, and even today, all high-powered marine engine cylinders are set upon posts and the sides between the cylinders and crankshaft left entirely open.

Crankcase Construction. Most crankcases are split longitudinally along the center line of the crankshaft. The upper half supports the cylinder and crankshaft and the weight of the engine on the chassis frame, and also has proper provision for the support of the various accessories upon it. The lower half, in such cases, is formed as a simple enclosing pan, with oil reservoir in the bottom. When the lubricant is circulated by pump, this is generally attached to the lower half of the crankcase, either inside or outside.

A section through a modern crankcase is shown in Fig. 78, which illustrates a twelve-cylinder motor. Note the inclined upper surfaces of the upper half to which the cylinders are bolted and the stiffening rib at the center line where the two halves meet. Note also how the lower half is simply an enclosure, carrying only the oil strainer (shown) and the oil pump (not shown). It has cooling fins cast on its lower surface to keep the temperature of the oil down. The shelf, which is cast on the upper half to close the space between the sides of the crankcase and the chassis frame, serves the double purpose of a protecting pan to keep out road dirt and water and of a supporting shelf for accessories. Fig. 79 shows the same engine from the front.

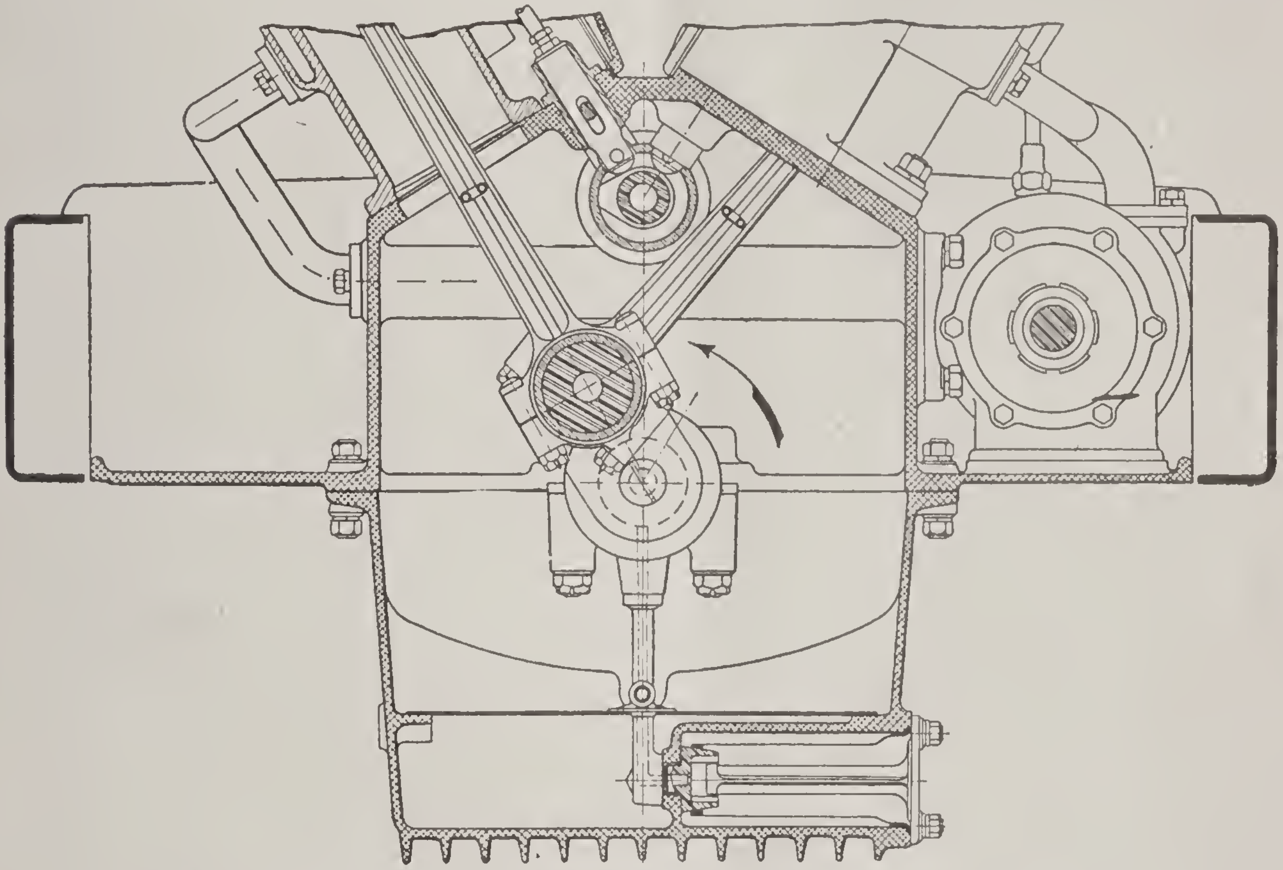


Fig. 78. Section through Crankcase of Box Type for Twelve-Cylinder V-Type Packard Motor

Crankcases are made mostly in two forms: the box type, which has more or less straight sides, with a flat top and bottom; and the barrel type, which is round or a modified round with a flat bottom and top. The one shown is of the box type; the barrel type is generally not split along the center line, but it has removable end plates which allow the insertion of the crankshaft and a very simple bottom plate which carries the oil supply. The one-piece type is supposed to give greater rigidity, but this is at the expense of accessibility.

Modern Tendencies in Design. There are two modern tendencies shaping toward a modification of, or the entire elimination of, the lower half of the crankcase as it is now known. One is the minimizing of its functions, so it can be made of pressed steel, when it becomes a cover only, and the oiling system is made such that the supply is carried elsewhere. The other is the casting of parts of the crankcase integrally with the cylinders. This has been done successfully with the Marmon, the Ford, and with others, in which the cylinder block and the upper half of the crankcase are cast as one. If this casting is considered as a cylinder unit, there is no upper half of crankcase. By extending this practice a little further, the lower half may be combined with cylinder block and upper half, so that the crankcase as we know it now would cease to exist.

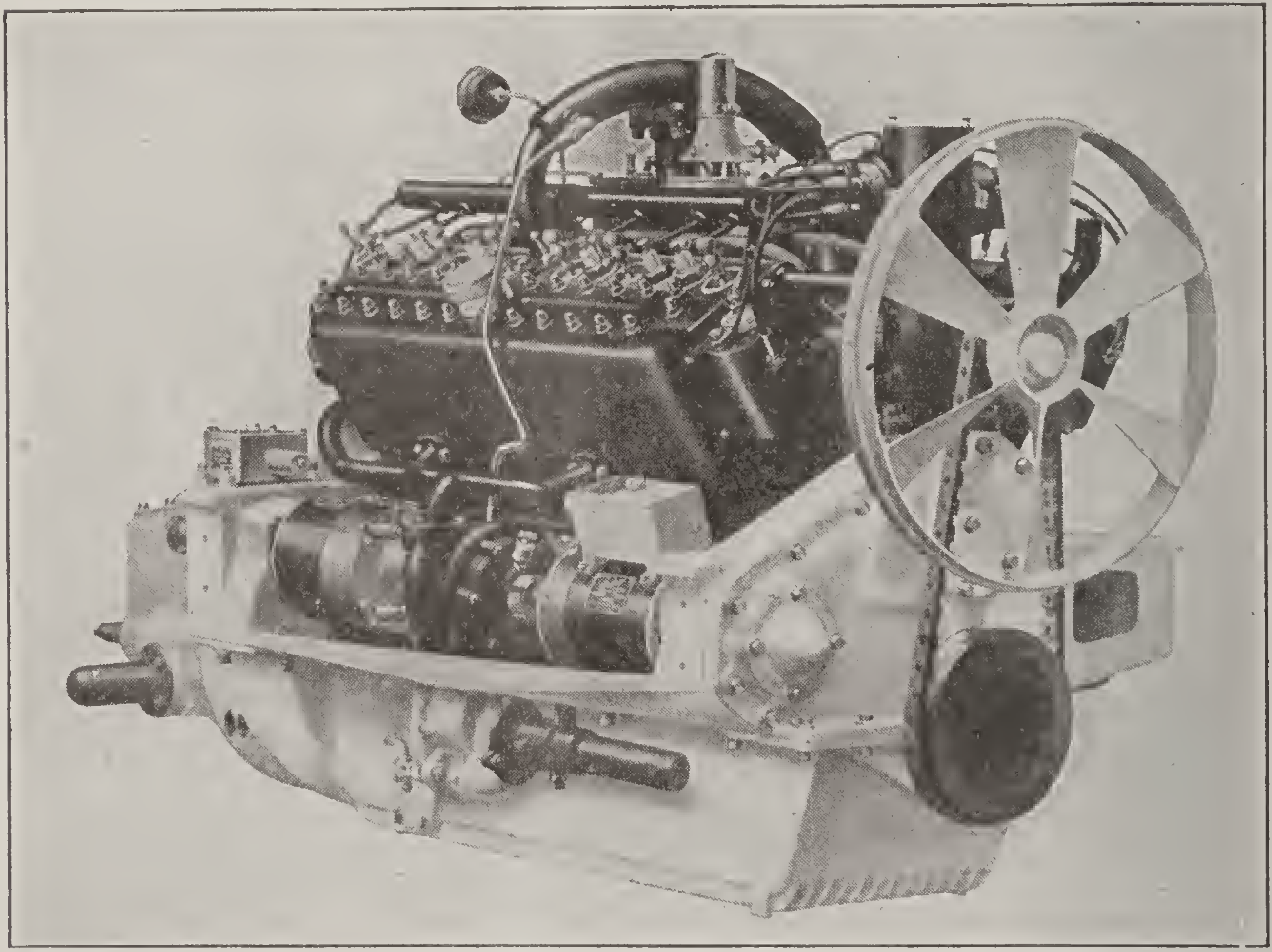


Fig. 79. Assembled Motor Shown in Section in Fig. 78
Courtesy of Packard Motor Car Company, Detroit, Michigan

All these combinations save weight and reduce cost. They also reduce the number of parts and make the car as a whole more simple. In some cases they go hand in hand with large production, as the pressed steel lower half of the crankcase calls for a big expenditure for dies. On the other hand, they may make the repair man's work greater. As, for instance, when the cylinders are combined with the crankcase, it is an all day's job to take out a piston and replace it. When the cylinders are separate, cast in pairs, or bolted on, a piston can be taken out and replaced in a couple of hours.

Crankcase Materials. It is important that the repair man should know the materials of which both upper and lower halves of the crankcase and the gear cover are composed, for these may need repairing. In general, crankcases are of aluminum alloy, the exact composition varying. When this is the material, the gear cover is of aluminum alloy also. A few crankcases are made of cast iron, on very low priced cars. Others have the pressed-steel oil pan, previously mentioned. A few high-grade cars have bronze crankcases; these are either government bronze or vanadium bronze.

Crankcase Arms and Engine Supports. The engine is generally supported by crankcase arms extended from the sides or ends of the upper half of the crankcase and cast integrally. However, this is not always the case. In many unit power plants, the rear pair of supporting arms may be fixed to the flywheel housing or to the transmission case. Moreover, separate supporting members bolted or hinged in place may be used. These are heavy steel forgings, stout bronze castings, or heavy gage steel tubing. This may be done to allow the engine freedom of slight rotation and relieve it of twisting due to road inequalities; it may be done because of lack of confidence in the strength of the crankcase material as an engine support; it may be done to facilitate foundry work on the crankcase, and thus reduce its cost; or for other reasons. In taking out an engine, the repair man should find out about this, as it may simplify or complicate the removal.

Gear Cases, or Gear Covers. At the front end of the great majority of engines, the gears which determine the working of the engine and its accessories are placed. These may include the crankshaft driving gear and any or all of the following driven gears: camshaft gear, magneto gear, water-pump gear, lighting-generator gear, oil-pump gear, and sometimes fan gear and air-pump gear. These may be driven directly by gear contact or by means of silent chains. In either case the gears are enclosed by a case or cover, variously called the gear case, gear cover, or cam-gear cover. This housing is generally of as simple a shape as possible, and is bolted in place with as few bolts as possible in the lower half of the crankcase, so as to facilitate its removal for crankshaft or other bearing inspection or for repair.

Other details of the crankcase parts, not previously discussed, will be taken up under the groups in which they belong; for instance, camshafts and cams with valves and valve parts; lubricating parts, drilling in crankshafts for lubricating purposes, oil passages in the crankcase, etc., under lubrication; and others under their respective groups.

Crankcase Troubles and Remedies

General Nature of Troubles. The most general crankcase trouble, aside from bearing trouble, is breakage. The usual bearing troubles previously outlined occur as well with main crankcase bearings. These require similar attention, and in their handling much special apparatus, such as stands, jigs, fixtures, and tools, can be developed by the ingenious repair man. Worn main bearings cause a knock. If this comes from any one bearing, it can usually be traced quickly. The use of the stethoscope is recommended for any crankcase or gear-cover noises or troubles. A squeak from any part of the crankcase usually means a lack of oil or the rubbing of parts which should not rub.

Mending Breaks. If the case is of aluminum, it should be watched carefully for breaks or cracks. If a crack develops, it should be drilled, plugged, and welded, as cylinder water jackets. This will prevent the crack from spreading. Any fairly large break means either undue stress or a weakness in the metal. The latter can be remedied by patching, by building up in the welding operation, or by the use of a new part. The repair man who is in doubt about his ability to repair a break or crack should always consult a welding expert, for welding can be done, and is being done daily, which would astonish those unfamiliar with the scope of the process. Moreover, it is relatively inexpensive. Quite often, a weld which would not cost more than $4 or $5, can be made the same day even by a fairly busy shop; otherwise it would mean a new case at a cost of perhaps 10 or 12 times as much, two weeks' delay or longer for delivery of the order, and the additional time and delay of detaching all the old accessories and fittings from the old case, and re-attaching them to the new case.

Cleaning Aluminum. Aluminum can be cleaned, externally, by means of a weak sulphuric-acid solution, say not more than 10 per cent sulphuric acid. This should be well scrubbed into the surface with a stiff brush, then washed off with water. Care should be taken to wash well enough and long enough to remove all the acid. Moreover, it should be kept from clothes or from any wood parts, as it is strong enough to attack fabrics and wood.

The aluminum oil pan should be cleaned out at least once a season, for the strainer will separate a lot of dirt and dust, as well as other foreign matter, from the oil in the course of 8 or 9 months. This will be found in the bottom of the oil pump or beneath the oil proper, as a kind of slush or sludge. Sometimes it is thick enough to need scraping, particularly in sandy country where the car gets little or no care. Generally, a kerosene bath will clean it out. This is followed by a "once-over" with gasoline to clean off the kerosene and the last of the dirt. If any gasoline remains, it will evaporate and leave a crankcase which actually is clean. The porosity of aluminum emphasizes this need for a thorough cleaning, which is not needed so badly with pressed-steel oil pans.

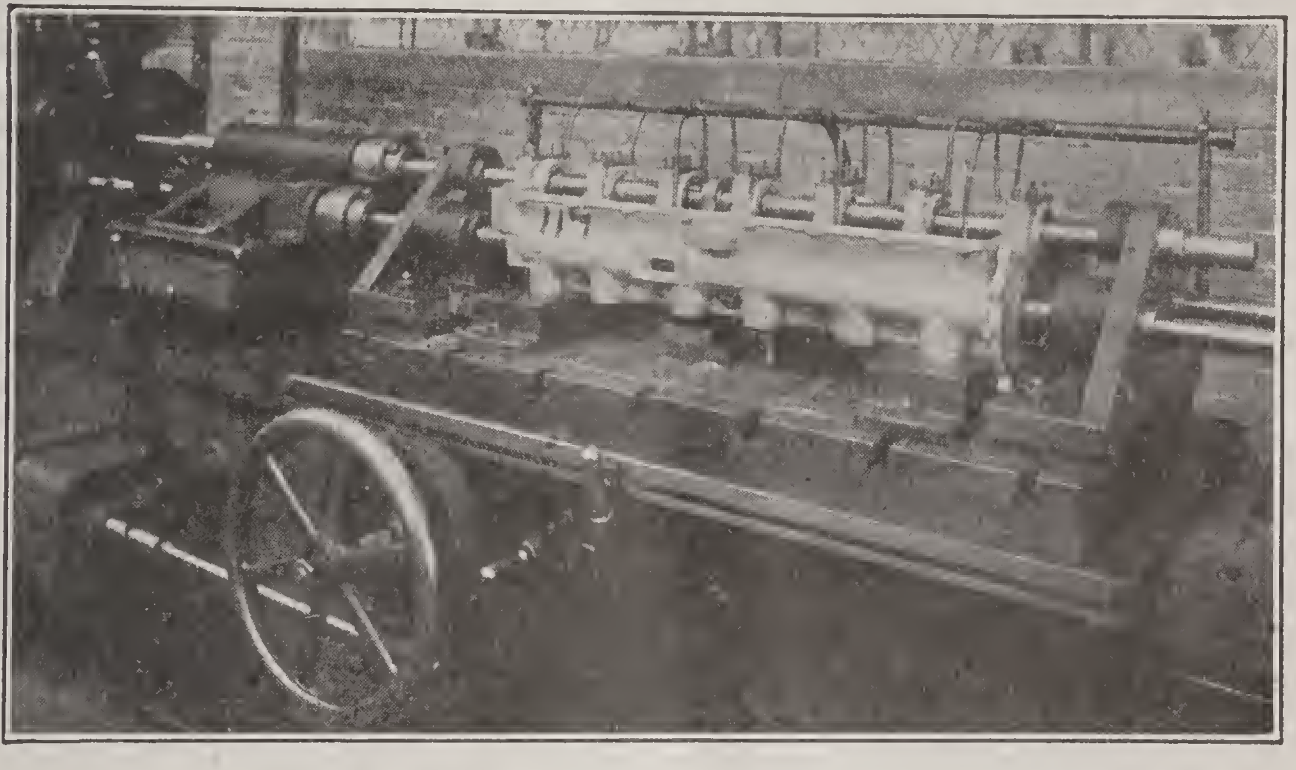


Fig. 80. Method of Boring Crankcase Bearings with Special Boring Bar
Courtesy of Pierce-Arrow Motor Car Company, Buffalo, New York

Machining Crankcases. Generally speaking, the repair man will not be called upon to do any machining on crankcases, beyond something like chipping or filing, or in the case of a break, patching or welding. But in case such a job should come along, it is important to know how to handle it, for there is no more important crankcase job than the machining of the main bearings. The necessity here is to keep them in perfect alignment, and this necessitates machining all of them at once with a long boring bar, as shown in Fig. 80. The method of support upon the flat upper, or cylinder, face will be noted, also the holding down blocks bolted to the table of the machine, after being bolted to the cylinder studs. The provision for lubricant on each one of the boring cutters will be seen in the small copper pipes above and at the back. As the average shop does not have a boring tool of this kind, this work will have to be approximated. It could be done by hand, using the now well-known Martell aligning reamer, to ream the bearings out and put in new and larger bushings. This also has a series of cutters, much like the boring bar shown, and is actuated by hand. So the principal requisite would be a large flat surface on which to work. Possibly this will be found at the drill-press platen, the planer table, or the working table of whatever large machine tool the shop possesses. In this job, the workmen should remember that unless the case is held firmly throughout, it is likely to give or spring, and this will spoil the whole job, no matter how good it may be otherwise.

In all crankcase repairs, the repair man should remember that the case is really the foundation of the engine, and if it is not firm of itself and firmly supported, the action of the engine cannot be positive nor continuous. Consequently the case should be handled with unusual care. Gear-cover troubles are few and far between, consisting mostly of breaks or trouble inside the cover with gears or driving chains. These will be discussed elsewhere. Usually, too, gear-cover lubrication is automatic, that is, one end of the crankshaft and crankcase-bearing lubrication system is continued forward to the gear cover, so that it gets all the surplus oil. In this way lubrication is cared for automatically, but the repair man should take no chances on this with cars under his care. He should remove the gear cover occasionally for inspection. Gear noises, too, emanate from the timing gears and are often due to a lack of lubricant there, or, to not enough thick lubricant to deaden the sound. Sometimes the construction of a gear causes a ringing noise, according to the form of construction used. Often whirring noises from the gear case are caused by burred teeth. The repair man can remove the burr with a file. Sometimes a chip of metal will get in between two gears and be pressed into the softer of the two; from that time on, it will cause noise continuously, and will also cut the other gear.

SUMMARY OF GENERAL AUTOMOBILE INSTRUCTIONS

Q. Into how many main groups can the mechanical parts of the car be divided?

A. Practically all motor cars can be divided into six general groups as follows: (1) engine, or power-producing, group; (2) clutch, or engine connecting and disconnecting, group; (3) transmission, or speed-varying, group; (4) final-drive group including rear wheels; (5) steering group for controlling the direction of the car and including front wheels and axle; (6) frame upon which all other groups except wheels are hung. The body makes a seventh group, but strictly speaking it is not mechanical.

Q. How many sub-groups are there pertaining to the engine?

A. According to their functions, the parts and accessories of the engine may be subdivided into 10 groups: (1) cylinders, pistons, connecting rods, crankshaft, and other basic parts; (2) carburetion sub-group through which the mixture is supplied which enables the engine to run; (3) valve group through which the mixture is allowed to enter and leave the cylinders at the correct time; (4) exhausting system through which the burned gases are led away from the motor; (5) ignition system by means of which the mixture in the cylinders is ignited at the proper time; (6) cooling system by means of which the temperature of the motor is kept down to a point at which it can operate safely and continuously; (7) lubrication sub-group by means of which the rotating, or rubbing, parts are kept lubricated so as to run without friction or heat; (8) starting sub-group by means of which the motor is started; (9) lighting sub-group through which the car is lighted, not strictly an engine part but closely allied with starting and ignition, and because of its drive from the engine and general location of its parts on it, it is classed as an engine sub-group; (10) flywheel sub-group. The last is really a single unit but its size, weight, shape, location, attachment, and other points are becoming so important as to warrant separate consideration.

Q. Why is it necessary to consider each of these separately?

A. Because their functions all differ. The very things which make each group best fitted to its work make it more widely different from each of the others. Some groups are so very different as to warrant separate consideration, almost as extended as the balance of the motor group, as, for instance, ignition, starting, and lighting, which naturally group together.

Q. What are the most popular cylinder forms?

A. Automobile engine cylinders are mainly of the following forms: (1) cast in pairs; (2) cast in block; (3) cast in threes, in the case of six-cylinder motors. The last is really a modification of the first.

Q. What are the advantages of each of these?

A. The cast-in-pairs form can be removed by one man and replaced by two, if it is broken, cracked, or damaged; replacement is less expensive; the casting is less complicated, consequently there is less waste in the foundry; they are easier to machine, store, ship, handle; they also have other advantages. All these apply to the cast-in-threes modification. The cast-in-block form makes a more simple looking engine, a shorter and more compact one, and renders alignment and spacing more accurate and permanent. Furthermore, all water, inlet, exhaust, and other connections may be cast integral, which is not possible with the cast-in-pairs or cast-in-threes forms. Similarly, the crankcase may be cast integral if desired.

Q. How is the weight of reciprocating parts lessened?

A. In the case of pistons, this may be done in one of three ways: (1) the form, shape, size, and material may remain unchanged, while the walls are machined thinner, or ribs are eliminated; (2) the material may be changed to a steel which can be machined thinner and smaller everywhere, thus saving a material amount; or (3) the material may be changed to an aluminum alloy which is lighter throughout, is strong to stand machining very thin in some places, and is so ribbed as to stand casting very thin in others. The first assumes that cast iron is retained; the second calls for a high quality of forged steel and is most expensive, so that it is used only on racing cars or cars of unusually high prices. The last is fast becoming the general method.

Q. What is the modern tendency in piston rings?

A. The experiences of aircraft engines and those in racing cars have taught that two well-made and well-fitted rings are sufficient. This is being applied rapidly to all motor-car engines by the removal of the extra and superfluous rings. Many motors had this number previously with an oil ring at the bottom, but it has been found that the removal of this makes little difference.

Q. Is there a noticeable tendency toward simplicity in connecting=rod constructions?

A. Yes, the same as in pistons and rings, toward simplification and lightening of the weight, with the removal of all superfluous parts. Two bolts are becoming the standard for the big end. The H-section machined all over is almost universal, smaller sections being used than formerly. Pressed-in wrist-pin bearings of comparatively thin walls are being used and a better class of material generally, which allows lighter weight and smaller sizes for equal or greater strength. Lubrication scoops are being machined-in in the forms of holds, and a simple projecting lip instead of former brass tubes, which were added.

Q. What is the accepted type of connecting=rod big=end bearing?

A. The split, or two-piece, form with a shell or backing of bronze and a facing, or wearing surface, of babbitt with oil holes drilled through and the interior surfaces oil-grooved to and from these to distribute the oil evenly.

Q. Why is this the accepted form?

A. The bronze backing or shell gives the desired stiffness and permanence, also machines well and resists overheating well. The babbitt facing, when worn, is easily replaced by any repair man, and it will melt out in case of lubrication neglect so little harm is done, yet when well-fitted it gives a fine bearing surface. The system of drilling and grooving supplies a film of oil at all times. These materials and this arrangement supply an almost ideal combination when well-made and fitted, hence their wide acceptance.

Q. What difference is noted in V=type engine bearings?

A. When the two rods of a V-type engine act upon a single pin, the arrangement of the bearings must be such that one must be notched out, or divided, to make room for the second, or else the exterior of the first must be formed as a bearing surface for the second. In the former case, the one bearing is practically in four parts; in the latter, the exterior of the inner bearing becomes as important as its interior surface, since it acts as the bearing pin for the outer rod.

Q. Name two general forms of crankshaft today.

A. The single-plane type and the multi-plane type. In the former, as used on four- and eight-cylinder engines, all pins, bearings, and webs are in one plane. In the latter, as used on six- and twelve-cylinder engines, the pins are in three planes set at an angle of 120 degrees with each other.

Q. How many different forms of four=cylinder shafts are there?

A. There are but three radically different forms of four-cylinder crankshafts, depending upon the bearings. These are: (1) The shaft in which there is a bearing on each side of each application of power, or five bearings in all; (2) the form in which there is a bearing at each end and one in the middle, or three bearings in all; (3) the form in which there are no center bearings, but only the two end bearings. The first is used on the highest-priced four-cylinder cars, because it is expensive of itself and has a similar influence on other parts, notably bearings, crankcase, etc. The second is in wide use; being the most popular form. The last is used only when extreme compactness is desired. There is an odd form of shaft in which four bearings are used, but only one maker ever used it.

Q. What is the difference in the average of six=cylinder crank=shafts?

A. Six-cylinder crankshafts differ about the same as fours, according to the number of bearings. There are the same number of different forms as follows: (1) with seven bearings, or one on each side of each application of power; (2) with four bearings, or one at each end and one between each pair of cylinders; (3) with three bearings, one at each end and one in the middle, used only with block-cast cylinders.

Q. What can you say of eight=cylinder crankshafts?

A. These vary the same as fours in general, the eight-cylinder motor having a four-cylinder shaft with perhaps slightly longer pins and of slightly larger diameter throughout.

Q. How do twelve=cylinder shafts vary?

A. They are the same as six-cylinder shafts, with the same variations as to bearings; in fact, all twelves have six-cylinder shafts with slightly longer and larger pins.

Q. Does counterbalancing effect the shaft?

A. No, except in outward appearance. The counterbalanced shaft is just the same as the shaft without counterbalancing masses.

The general type is the same, also the number of bearings. This applies to fours, sixes, eights, twelves, or to any form.

Q. What are shims, and for what are they used?

A. Shims are very thin pieces of metal placed between the two halves of bearing caps for the purpose of giving a quick, simple, easy adjustment when the bearing wears. In theory, this works as follows: When a bearing has worn down $\frac{2}{1000}$ inch, the cap is unscrewed and removed, and shims of a thickness of $\frac{2}{1000}$ inch are taken out on each side. Then the cap is replaced and tightened, and the bearing is as good as new. In actual practice, the removal of the shims creates a shape of bearing which is not an exact circle, so that some slight scraping with very little wear, is necessary, as illustrated above, and a great deal of rescraping and refitting (in addition to shim removal) with greater wear.

Q. For what is a crankcase used?

A. The crankcase is used to support the cylinders and the crankshaft; to act as a housing to keep out dust and dirt and as a retainer and reservoir to hold the oil in.

Q. What is its general shape?

A. Generally, crankcases are either of the box shape or of the round, or barrel, type. The first named is generally split horizontally along the crankshaft center line; has a flat top and bottom, with vertical sides; has the bearings supported in the top half only, the bottom acting simply as an oil pan. The second form is generally in one piece with removable ends in which two of the shaft bearings are located; has a rounded bottom in which the oil is held; has a flat top but rounded sides.

Q. Of what material is the crankcase constructed generally?

A. Aluminum and aluminum alloys are most widely used, although there are a number of motors with cast iron, some with a cast-iron upper half and a pressed-steel or aluminum lower half, and a few of bronze. The latter is expensive and is losing ground. Pressed steel is suitable only for quantity production, while cast iron is losing ground except in those up-to-date designs in which the upper half of the case is combined with the cylinder block.

Q. How are crankcases supported on the frames?

A. The most general method on pleasure cars is the casting of arms, generally four, integral with the crankcase, these extending out to and resting upon the frame, to and through which they are fastened. Generally, too, a thin web is cast between the front and the rear arm on each side, extending out horizontally from the sides of the case to the frame. This serves the double purpose of replacing the underpan and of acting as a stiffener for both arms and case. On a few cars and on quite a few trucks, a pivoted cross-arm is used at the front and a bolt cross-arm at the rear (or *vice versa*), these being forged members. In this way a three-point support is obtained, which yields as the frame is twisted or raised unequally.

Q. What is the gear cover and what are its functions?

A. It is the removable cover at the front end of the engine, which covers and protects the camshaft and other gears or silent-chain drives. In addition to keeping out dust and dirt from these, it minimizes the unavoidable noises which they make and retains the lubricant. It is generally a light aluminum shell held on by a dozen or less bolts.

Q. What is the general method of lifting an engine out of the frame?

A. By a rope or a chain sling, hoisted from above by a chain hoist, block and tackle, overhead crane, or movable floor crane. The latter are of recent introduction but have the advantage over the overhead form that they can be rolled around the garage or repair shop to any needed point, while the overhead form is useful only under its track or runway. In addition, they can be put into use more quickly on a rush job, take up little room, and cost no more than the overhead built-in form.

Q. How are engine stands useful?

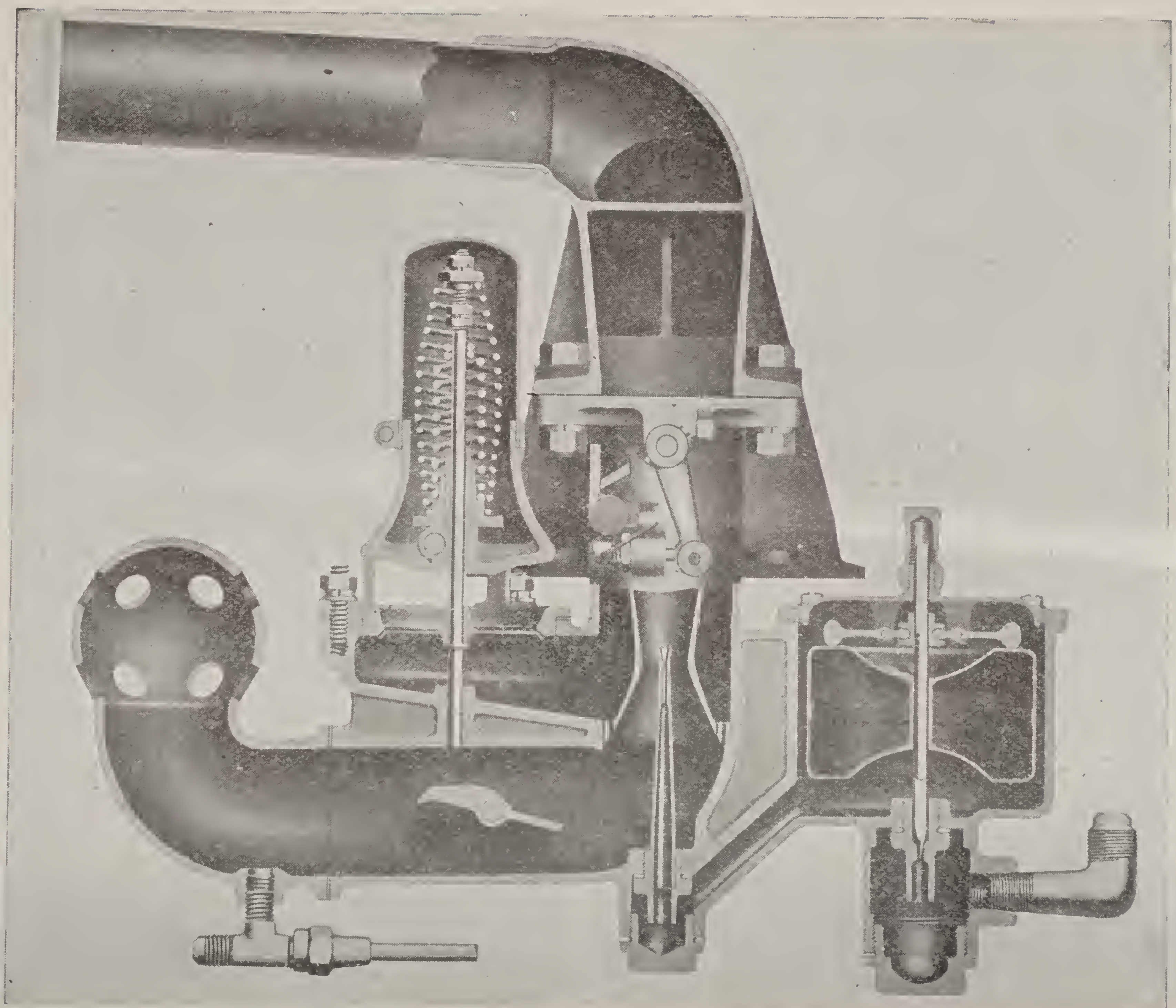
A. They hold the engine in a convenient place and at a reasonable working height. They hold it firmly so that pressure can be exerted if necessary or hammering can be done. Moreover, if rightly constructed, they allow rotating the engine to do work upon the sides or bottom. In these and other ways they save much time and trouble, hasten the work, and thus cut the cost. In addition, their convenience allows of doing better work.

Q. Is there any best method of removing carbon from cylinders?

A. The method depends upon the design and the construction of the motor, the quantity and the hardness of the carbon and its location in the cylinder, and, in part, upon the facilities which the shop possesses. The best method varies with almost every case.

Q. What is the most rapid method?

A. Probably burning out with oxygen is the quickest method, when the shop possesses an oxygen-burning outfit. The spark plugs are removed and their holes plugged, one or more valve caps are removed to allow working, the gas is turned on and lighted, when the workman can do a cylinder thoroughly in three or four minutes. This means that the entire process of doing an engine will not take over twenty-five to thirty minutes. Any other process will take twice as long as this.



PACKARD CARBURETOR USED ON "TWIN SIXES"

Courtesy of Packard Motor Car Company, Detroit, Michigan

GASOLINE AUTOMOBILES

PART II

ENGINE-GROUP ELEMENTS—(Continued)

CARBURETORS AND CARBURETION

Function of the Carburetor. As has been pointed out in the general outline of the motor car, the first and most important thing in the engine cycle is to get the fuel into the cylinders. This is done through the medium of the carburetion system, the principal unit in which is the carburetor. The function of this is to convert a liquid (gasoline) into gas (gasoline vapor) measure this, and add to it the right quantity of air to give proper and complete combustion. If this be not done, power is lost, either through the use of too much or too little air. In the latter case, not all the fuel is vaporized, hence some of it is wasted.

This sounds like a simple proposition, yet its very simplicity has been the undoing of many automobile experts. The vaporizer becomes more and more complex each year, constant additions and changes are being made in the other parts of the system, and in other ways the carburetion system shows a constant change. Despite all this, few fundamental laws have been found to be in error, and few new ones have been discovered or developed.

Effect of Heavier Fuels. For some years past there has been under way a subtle change in the character of the fuel—the gasoline used for the propulsion of automobiles. The small production and the increasing demand have combined to render almost unpurchasable, except at high prices and then from large dealers, the lighter and more volatile gasolines of some years ago. In the place of them there have been quietly introduced much heavier petroleum distillates, which evaporate less readily—though they are actually of higher value in terms of power units. This condition has compelled several changes in the carburetor problem.

In addition to the foregoing, in some parts of the world there have been serious efforts made to utilize in automobile motors alcohol and benzene (not benzine), which, with proper provision for their carburetion, constitute excellent fuels.

The most important of the changes dictated by this development in the fuel situation is the now general practice of heating the float chambers of carburetors, either by water from the circulating system or by exhaust gases. An alternative scheme is that of drawing of the air for the carburetor from a point adjacent to the exhaust piping, so that this air is sufficiently warmed to readily take up the gasoline necessary to constitute a proper explosive mixture.

Jacketed Manifolds. A subsequent and very successful method of handling the heavier fuels is that of jacketing the upper portion of the inlet manifold, and the circulating of the hot water in the cylinder-cooling system through this. By having this jacket close to the point where the gaseous mixture enters the cylinder, any remaining particles of liquid fuel are vaporized before entering the cylinders. In a few instances, the same effect is obtained by incorporating the carburetor in the cylinder water-jacket casting. In still others, where the carburetor is placed on one side and the inlet valves on the other, there is a cored inlet passage through the cylinder block between the cylinders which heats the mixture, with the same result as stated above.

Fuel Injection. Systems of fuel feeding by direct injection of minute quantities of the combustible liquid into the cylinders or into the intake piping have been advocated or experimented with for many years, and have found very successful application in stationary and flight engineering, though as yet not one of these sytems has successfully competed with the carburetor in automobile service, where the conditions of power variation are such that fuel injection has not seemed readily applicable.

Nevertheless, there are many engineers who adhere to the view that sooner or later fuel injection will supplant present systems of carburetion, and progress made recently with aviation motors of fuel-injection types may seem in some measure to justify this view.

Despite the success of this system on aeroplane and stationary engines—notably on the Antoinette and the Diesel, respectively—there is not, to the writer's knowledge, a single American motor-car manufacturer now using or experimenting with fuel injection. A few years ago a motor car brought out in the Middle West used it, but this was short-lived. Since then, nothing has been done.

More Valves vs. Forced Induction. The present-day tendency toward the use of many valves, four per cylinder, seems to indicate a necessity for getting more gas into the cylinders in order to get more power and speed from the same size of motor. This would seem to lead back to the subject, agitated a few years ago and dropped for lack of interest, of the need for forced induction. This will introduce a greater quantity of gas into the cylinders without resorting to the complications and trouble-breeding possibilities of four valves per cylinder. It differs widely from fuel injection, consisting in its simplest form of a special form of fan or blower to drive the vaporized fuel into the cylinders.

Classification of Carburetors. Carburetors, as a whole, may be divided into three classes: the surface form, in which the air passing over the surface of the fuel picks up some of it, mixes with it, and produces an explosive vapor; the ebullition, or filtering, type, in which air is forced through a body of fuel from below, absorbing small particles so that when it reaches the top and is drawn off, it is suitable for use in the cylinders; and the float-feed, or spraying, type, under which head nearly all modern devices come. The others have gone out of use, as fuels today are too heavy for them to be practicable.

The original float-feed carburetor consisted of one part besides the fuel pipe, float chamber, and passage to cylinder, which made it remarkable for its simplicity. It had no adjustments, nor was there any way of securing an even and continuous flow of fuel or of air, except as the engine suction produced these. The need for these qualities brought out, one by one, the modifications of the original; and through continuous modifications and recombinations of these, all the modern devices have been developed.

Defects in the Original Are Not Found in Modern Types. The original carburetor had no adjustment; the opening in the casting measured the amount of air, while the size of the nozzle measured the amount of the fuel and the fineness of the spray. There was no means of regrinding the float valve, and thus no way of assuring an even and continuous flow of fuel. The modern adjuncts of the original Maybach device consist of remedies for these defects, and, in addition, a proper means of balancing and adjusting the float.

To pick out a modern carburetor at random, take the one shown in Fig. 81. Like its ancestor, it has a gasoline chamber into which

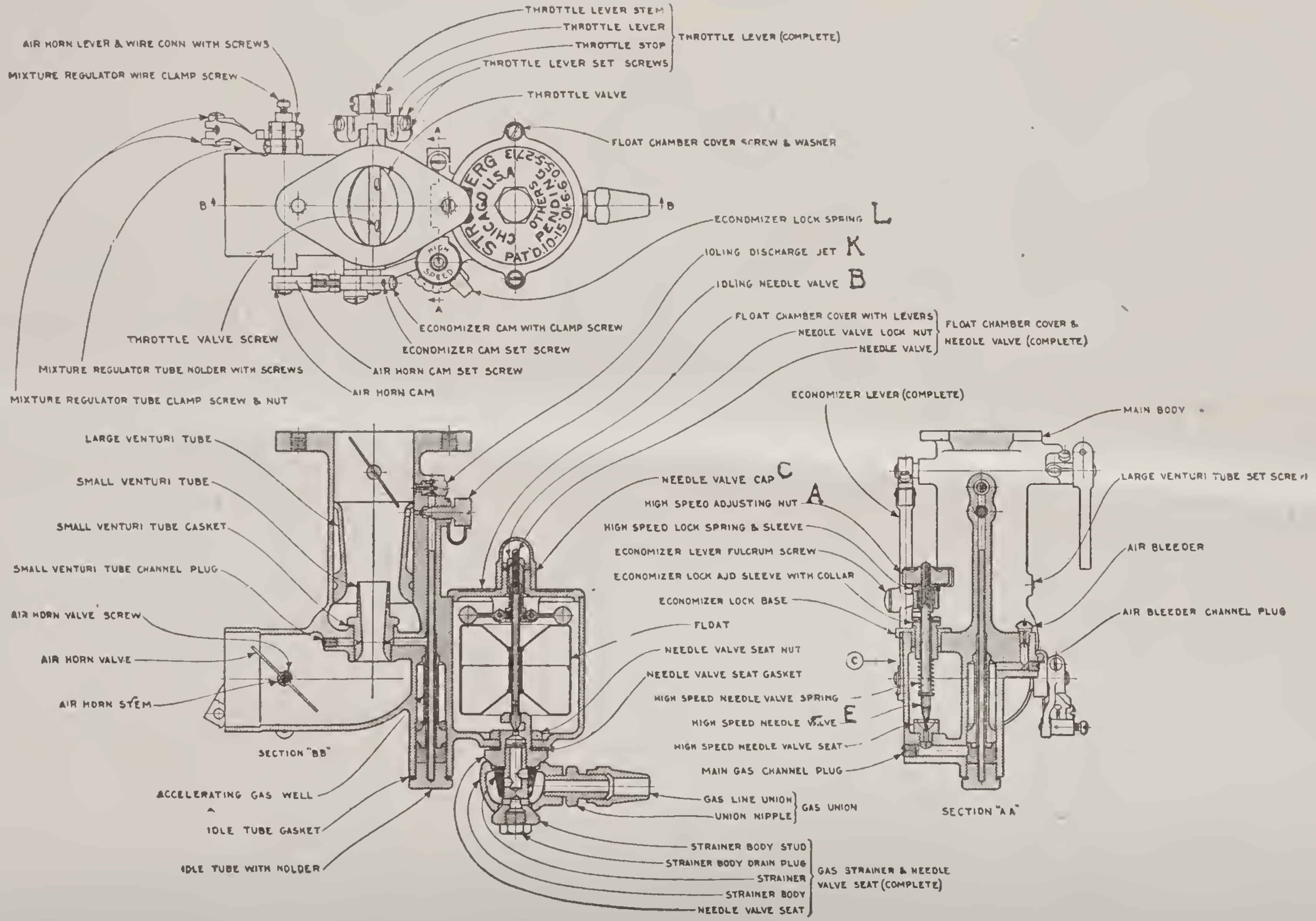

THROTTLE LEVER STEM
THROTTLE LEVER
THROTTLE STOP
THROTTLE LEVER SET SCREWS
THROTTLE LEVER (COMPLETE)
AIR HORN LEVER & WIRE CONN WITH SCREWS
MIXTURE REGULATOR WIRE CLAMP SCREW
THROTTLE VALVE
FLOAT CHAMBER COVER SCREW & WASHER
STROMBERG CHICAGO U.S.A. PAT'D.10-15-01-6-9-05-5-27-13 OTHERS PENDING
HIGH SPEED
B
B
A
A
ECONOMIZER LOCK SPRING L
IDLING DISCHARGE JET K
IDLING NEEDLE VALVE B
THROTTLE VALVE SCREW
ECONOMIZER CAM WITH CLAMP SCREW
ECONOMIZER CAM SET SCREW
AIR HORN CAM SET SCREW
AIR HORN CAM
MIXTURE REGULATOR TUBE HOLDER WITH SCREWS
MIXTURE REGULATOR TUBE CLAMP SCREW & NUT
FLOAT CHAMBER COVER WITH LEVERS
NEEDLE VALVE LOCK NUT
NEEDLE VALVE
FLOAT CHAMBER COVER & NEEDLE VALVE (COMPLETE)
ECONOMIZER LEVER (COMPLETE)
MAIN BODY
LARGE VENTURI TUBE SET SCREW
AIR BLEEDER
AIR BLEEDER CHANNEL PLUG
LARGE VENTURI TUBE
SMALL VENTURI TUBE
SMALL VENTURI TUBE GASKET
SMALL VENTURI TUBE CHANNEL PLUG
AIR HORN VALVE SCREW
AIR HORN VALVE
AIR HORN STEM
SECTION "BB"
ACCELERATING GAS WELL
IDLE TUBE GASKET
IDLE TUBE WITH HOLDER
NEEDLE VALVE CAP C
HIGH SPEED ADJUSTING NUT A
HIGH SPEED LOCK SPRING & SLEEVE
ECONOMIZER LEVER FULCRUM SCREW
ECONOMIZER LOCK ADJ SLEEVE WITH COLLAR
ECONOMIZER LOCK BASE
FLOAT
NEEDLE VALVE SEAT NUT
NEEDLE VALVE SEAT GASKET
HIGH SPEED NEEDLE VALVE SPRING
HIGH SPEED NEEDLE VALVE E
HIGH SPEED NEEDLE VALVE SEAT
MAIN GAS CHANNEL PLUG
GAS LINE UNION
UNION NIPPLE
GAS UNION
C
SECTION "AA"
STRAINER BODY STUD
STRAINER BODY DRAIN PLUG
STRAINER
STRAINER BODY
NEEDLE VALVE SEAT
GAS STRAINER & NEEDLE VALVE SEAT (COMPLETE)

Fig. 81. Stromberg Model "L" Carburetor
Courtesy Stromberg Carburetor Company, Chicago

the fuel is admitted by the action of a float, when it first passes through a strainer. From the float chamber the liquid passes up to and through the spraying nozzle. The weight of the float is so calculated that the level in the final nozzle is just 1 millimeter (0.04 inch) below the top. This insures that there will always be fuel there for the air suction to draw off. As the physical action of changing a substance from a liquid to a gas is usually accompanied by the absorption of heat, it is advisable to supply a reasonable amount of this, and thus assist the change of form. In the older Maybach, this was inadvertently done by placing the whole apparatus in close contact with the hot cylinder. In the modern carburetor, placed some distance from the heated portions of the engine, this additional heat is supplied by the jacket water. An alternate scheme is to pre-heat the air supply by a special pipe from the exhaust manifold.

From this mixing chamber the mixture of air and gasoline vapor passes upward into a secondary mixing chamber. This communicates with the inlet pipe through the medium of the throttle valve. The auxiliary air supply, when used, has access into the secondary chamber through the auxiliary air valve. This comes into action on very high speeds when the engine is pulling very strongly. At this time the proportion of gasoline to air is likely to be too large, so the auxiliary opens, admits more air, and thus dilutes the mixture.

Throttle Valves. *Butterfly Type.* Whatever the nature of the mixture in the carburetor, it is admitted to the cylinder by the throttle valve, which may take the form known as the butterfly. This is a flat piece of sheet metal, preferably brass, attached to a suitable shaft with an operating lever on the external end.

Piston Type. Besides the butterfly type there are fully as many of the piston type. The sliding form is a cylindrical ring or shell of metal, which is free to slide in a corresponding cylindrical chamber. In the walls of the latter are a number of apertures or ports which the longitudinal movement of the piston either uncovers or covers as the case may be. Sometimes, to facilitate this action, the sides of the piston are grooved or notched, but this does not alter the principle of sliding a cylinder within another cylinder to cover or uncover certain ports in the cylinder walls.

In addition to the sliding piston, there is the rotating piston, working in practically the same manner, that is, its rotation connects openings in the piston walls with the interior of the vaporizing chamber on one side and with the inlet manifold on the other, the amount of the opening depending upon the distance the piston is rotated.

Needle Valves. Needle valves—or spray nozzles as they are sometimes called because of the function they perform—constitute an important part of every carburetor, or liquid-vaporizing device. It might be thought that so long as there is a hole by which the fuel can enter the vaporizing chamber that is sufficient; yet such is far from the case. In addition to the function of an entering hole, the needle has the additional duty of breaking the fuel up into a fine spray or mist, the particles of which are easily picked up by the inrushing air, and as easily converted into a vapor. Therefore, that shape, form, or arrangement which will divide the entering liquid up into the finest particles will be the most efficient. The difference of opinion on this latter point has produced the large number of shapes of nozzle and needle which are now in use.

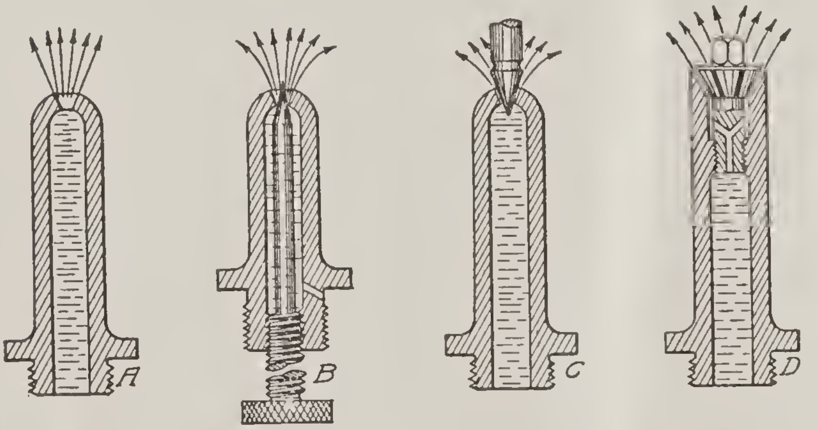


Fig. 82. The Four Usual Shapes of Gasoline Needle Valves and Spray Nozzles

Simple Vertical Tube. In general, practically all these can be divided into four groups, illustrated in Fig. 82. The one at *A* is a simple round vertical tube with an opening in the top, through which the liquid may pass out. It does not alter the type if the sides of the opening converge, diverge, or are straight, but it will influence the resulting spray somewhat. Of the twelve makes shown with this type, practically all indicate the opening as straight, but this may be due to the small size of the drawing which does not make the taper apparent.

Internal Needle Type. Type *B*, Fig. 82, is similar to the first, except that an adjustable pointed needle is added on the inside. This occupies most of the center space, forcing the liquid to pass out in a smaller circular sheet or stream than would be the case with Type *A*, considering equal-sized holes. In addition, the fact that the internal needle valve may be raised or lowered allows this stream to vary greatly, both as to quantity of fuel flowing, and the extent to which it is spread out. When the needle is down very low, only its point enters the hole, so that practically the full area of the latter is available, the central needle influencing the column of fuel passing out only to make it hollow in the center.

With the needle raised to nearly its maximum height, however, the point projects clear through, and the needle shaft almost fills the lower part of the hole. This reduces the flow to a very fine hollow column of spray, as the shape of the needle and of the lower edge of the hole is such as to force it inward and then outward so that as it leaves the top of the hole it is diverging widely. Thus, the effect of the addition of the needle is to allow the use of much smaller quantities of liquid with the same-sized hole, of diffusing it more widely, and of making it adjustable to varying needs. Despite all its advantages, only three of the carburetors and vaporizers shown use this type; and of these, one is a combination of this with *A*.

External Needle Type. The third type shown at *C*, Fig. 82, is an inversion of *B* in that the needle is made external and descends from above into the hole in the nozzle. In this form, the shape of the needle point produces the desired diffusion and spraying effect, which accounts for its popularity. Of the models shown herewith, nine are of this kind, one being a modified combination of this form and *A*.

External Sectional Needle Type. The fourth form, shown at *D*, is like *C*, except that instead of a needle resting upon the upper surface of the hole and allowing a continuous hollow stream of fuel to flow, a series of holes break up the column into a number of very much smaller columns, each with its own opening. In this form the central member may be movable or not, while the holes may be set at any angle. Of the examples of this form shown in this article, three in all, every one has the holes placed horizontally instead of inclined to a vertical, as shown in Fig. 82. Of these, two show a combination of *B* and *D*. This is an effective combination.

Floats. Another feature of the earlier forms of carburetors, which was soon found to be in need of a change, was the arrangement of the float. In Maybach's original vaporizer, there was no means of balancing the float; consequently, there was no way of preventing wrenching and breaking of the needle-valve spindle. As this disarranged the gasoline supply, it made a change very important;

and this problem received early attention. There was also the necessity for reliable devices to regulate the supply of air and of gasoline spray from the nozzle, either by original adjustment, by means of a governor, or by effecting a constant variation by hand to meet constantly varying conditions of engine demands.

These additions to the original form caused some trouble. The ordinary way of managing the balancing of the float, while it may be the cause of trouble at times, is a very simple one. The float is of exceeding lightness, whether made of cork or metal. With the inflow of gasoline in liquid form this float rises, and in so doing it strikes against a pair of small pivoted levers near the top of the float chamber. The other ends of the pivoted levers rest upon a form of shifting collar on the needle-valve stem. So, when the float rises above a certain level, it automatically shuts off the flow of gasoline by pressing against the pivoted levers, which, in turn, act against the stem and press it down until the flow is cut off. The float will stay up until the suction of the engine has lowered the gasoline level so that the dropping of the float releases the levers which raise the needle valve off its seat. The gasoline flow is thus automatically regulated by this balanced-float arrangement.

ADJUSTMENT OF AIR AND GASOLINE SUPPLY

Methods of Handling Fuel Spray. Probably no one detail of the whole list of carburetor parts has caused, and still does cause, more difference of opinion than the source of and adjustment of the air supply, and its companion, the adjustment of the gasoline spray. The latter drew attention long before the former; in fact, the former is more of a modern appliance. The fuel spray was investigated long ago; for the gasoline spray had no adjustment, but the size and the location of the level of the nozzle were fixed. The spray itself, however, received special treatment. It was projected against a conical spray deflector which served to break up the column into finer and more diffused particles. In this way, greater vaporizing action was gained.

Water-Jacketing. Longuemare was among the first to use a water jacket around the vaporizing chamber. The conversion of a liquid into a gas is an endothermic reaction and requires heat for its completion. If this is not supplied by external means, it will be extracted from surrounding objects. This accounts for the frost which gathers on the outside of the mixing chambers of carburetors which do not have a water jacket or other source of heat supply. The heat is abstracted from the air so rapidly that the moisture in the air is frozen, appearing as frost on the outside of the carburetor.

Auxiliary Air Valve. The auxiliary air valve has always caused discussion, its opponents claiming that it means extra parts, and therefore more adjustments and more sources of trouble; while those favoring it say that without some additional means of this sort for diluting the mixture at high speeds, it is impossible to run the engine fast, as high speed will then mean an over-rich charge. Be that as it may, the fact remains that the weight of opinion lies with the auxiliary valve.

Necessity with Heavy Fuels. Practically all the more modern vaporizers use an auxiliary air valve, as this is a partial necessity with the heavier fuels. That is, it has been found that the heavier fuels require more air to vaporize them than can be supplied by the primary air inlet. Moreover, these heavy fuels require considerable additional heat in order to vaporize, and the auxiliary air inlet has been made the vehicle for conveying this. As will be explained in detail later on, this is generally connected with the exhaust manifold in such a way that the air entering through it is heated to a high temperature. Adding this after the fuel has been split up by the spraying nozzle and the primary air has proved very successful.

Usual Forms of Auxiliary Air=Inlet Valve. The auxiliary air inlet usually consists of a simple valve, opening inward, held in its place by a spring of a certain known tension. The strength of the spring is carefully determined so that at the proper moment—when the motor requires more air in proportion to the amount of gasoline used—the valve will open just enough to allow the required amount of air to enter. It will be seen that the time and the amount of opening will be controlled by the speed of the engine, i.e., by the amount of suction produced by the movement of the piston in the cylinder. Of course, as the engine speeds up, there is a greater piston displacement to be filled per minute, and therefore it is necessary to supply a greater amount of mixture. Upon changing speed suddenly from, say, 500 revolutions to 900 or 1000, the carburetor which does not have this device will *not* give a uniform mixture immediately; in fact, it might require a new adjustment of the gasoline flow in order to supply the right amount of fuel. What the auxiliary air inlet actually does, then, is to control automatically, above a certain point, the amount of air admitted, thereby always maintaining a homogeneous mixture. In order to prevent any chattering of the valve or rapid changes in the air supply, a diaphragm or a dashpot is sometimes used in connection with the valve.

As a substitute for an auxiliary air valve, a number of makers have tried the use of steel balls, resting in holes about two-thirds the diameter of the ball. By varying the size and weight of the balls, a truly progressive action is obtained, for light suction lifts the light balls, and strong suction all balls.

Venturi-Tube Mixing Chamber. Like every other carburetor part, the spraying action and the shape or size of the chamber in which it takes place have been the subject of much debate. Originally, the chamber took any convenient shape and varied all the way from a perfectly plain cylindrical shape to an equally perfect square, with all the possible variations in between. A few years ago, however, scientists began to look into the vaporizing and equally important measuring action of carburetors, with the result that a new shape came into use, which was based upon a scientific principle.

This is the principle of the Venturi meter used for measuring the flow of water, and from its use the tube, or chamber, having this shape has come to be known as a Venturi tube. In form, this consists of two cone-shaped tubes diverging in opposite directions from a common point, which in the water meter is the *point of measurement* and in the carburetor is the *point of location* of the spray nozzle. The principle is that if these two frustrums of cones are of the proper shape, i.e., include the proper angle and are correctly set with relation to one another, the flow of air and gas will be in correct proportions to each other at all speeds, assuming first that the air enters at the bottom of the tube having the greater angle.

As a proof of the soundness of the principle of this type of vaporizing chamber, it might be said that the majority of carburetors in use today have it incorporated in one form or another. Many make the upper tube conical for a very short distance, beyond which it assumes a cylindrical form. In the true Venturi shape, the usual angle at the bottom is 30 degrees, while that at the top is 5 degrees.

In water meters the contracted area is made one-ninth that of the pipe. This same relation, although not exact, holds in the case of the carburetor. Since the area varies as the square of the diameter, this is equivalent to saying that the diameter of the contraction should be one-third the diameter of the full-sized pipe.

Double=Nozzle Type. A distinctive design of two connections leading into the vaporization chamber is the Zenith (French) carburetor, a diagrammatic sketch being shown in Fig. 83. This is but a modification, in a way, of the Venturi plan, for the latter shape is actually used for the vaporizing chamber. The new idea consists in leading into this mixing chamber, two tubes. Of these, one is the ordinary spray nozzle and does not differ from that used on hundreds

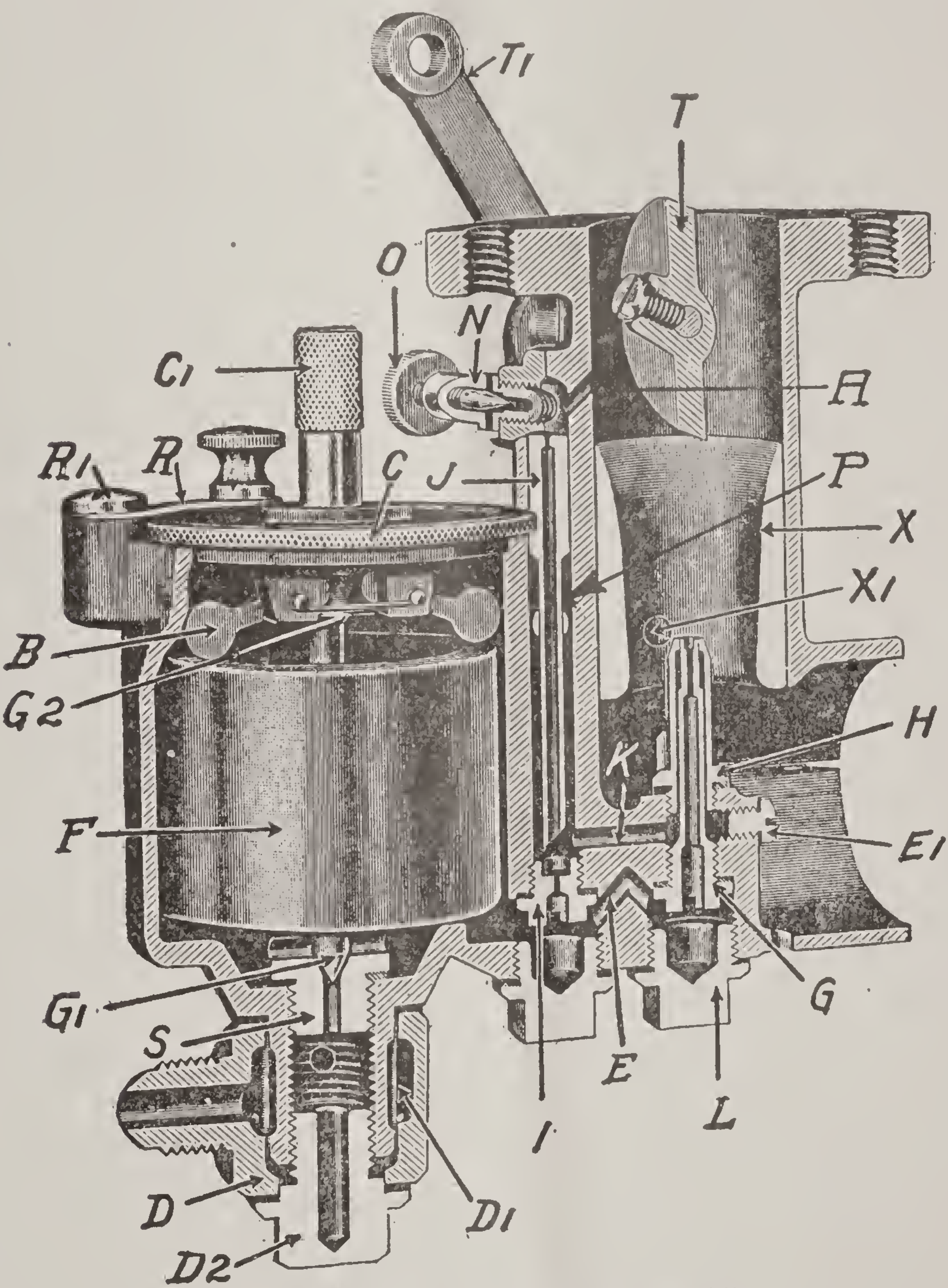


Fig. 83. Zenith Carburetor, Model "O"
Courtesy of Zenith Carburetor Company, Detroit, Michigan

of other devices. The second, however, is very different. While it leads into the same mixing chamber, it does so through the medium of a secondary chamber, or standpipe, to which the suction of the engine has access. If this suction is strong, more gasoline is drawn into the secondary chamber, from which it may enter the spraying zone.

The ordinary nozzle is of an exact size and, consequently, can pass only a certain amount of fuel, always at the same speed. With the additional nozzle, this does not hold; and being of large diameter (comparatively), the flow through it depends wholly upon the engine suction, which varies at all speeds, often at the same speed upon different occasions.

Use of By-Pass. This matter of two standpipes has a parallel in the use of a by-pass, so-called, around the usual mixing chamber. On some carburetors this is made so as to allow easy starting, the idea being that when suction is applied to the carburetor by cranking, with the throttle closed, practically pure gasoline vapor will be drawn through the by-pass. This will start the engine after which, as the throttle is opened gradually, its movement cuts off the by-pass, until at medium speeds it is out of use entirely. The same thing applies to the use of a secondary tube or standpipe for low-speed running.

A by-pass of a separate nature is made use of for starting and priming purposes; this consists of a small separate tank of gasoline attached to the dashboard under the hood, with a valve running through to the driver's side for turning on the supply. This is connected into the inlet manifold above the carburetor by means of a special pipe tapped into the manifold. When it is desired to start the motor, it is primed with this device by simply turning on the supply. Some gasoline flows into the manifold, and after a few seconds it vaporizes. The motor is than cranked over sharply, and a start is almost certain. This has the advantage of simplicity, accessibility, and low cost. In addition, it is economical of time as compared with lifting the hood to prime each cylinder separately.

Nature of New Developments. *Horizontal Carburetor Outlets.* Among the newest carburetor features are some which have worked themselves out naturally, and others which have been forced by changes in engine design, in fuel quality, etc. Thus the tendency toward block motors, and with it the tendency toward neat lines and simplicity, has brought forth a general simplification, or elimination of inlet pipes, and a fairly wide use of horizontal carburetor outlets. The latter has affected carburetors by requiring a shorter and more compact instrument, with a side outlet and a vaporizing arrangement which will produce tolerably complete vaporization in a comparatively short distance. To a certain extent, this horizontal-carburetor tendency has modified existing practice in nozzles, Venturi tubes, interior areas and arrangements, etc.

Effect of Heavier Fuels. The growing realization by carburetor manufacturers that the increased use of heavier fuels is inevitable has brought forth much worthy effort in the way of vaporizing them. This has temporarily set aside the kerosene and other heavy-fuel vaporizers. However, as the fuel is bound to become heavier and heavier, on account of the excessive demands for gasoline, it is only a question of a year or so before kerosene and distillate vaporizers will be agitated again.

Effect of Vacuum Feeds. The wide use of vacuum feeding devices, combined with the tendency mentioned above to clean and simplify, has caused a much higher mounting of carburetors. This has always been desirable, but hitherto it has not been possible. The vacuum feed for the gasoline supply has made this change possible, while the cleaning process and simplification actually forced it.

Effect of Motor Changes. The high-speed form of motor now so generally being adopted has had a big influence, as have also the multi-cylinder forms, both creating a demand for greater acceleration. Similarly, starting devices have forced the use of a carburetor modification by which instant starting is possible. These requirements have called for new designs, smaller and lighter parts, more nearly complete automatic actions to uncover large air ports, as well as other improvements.

Double Carburetors for Multi-Cylinder Motors. While many eight- and twelve-cylinder motors have but a larger-sized plain carburetor, the better forms have a double device, each half supplying a group of cylinders, and the halves are entirely separate and distinct from the other, except for a common fuel-supply pipe. Each set of cylinders has its own suction-actuated nozzle and its own independent nozzle. This form has shown its worth in actual use, having been very successful in aeroplane work on eight-cylinder and twelve-cylinder motors, and also on a number of the better eight- and twelve-cylinder motor cars.

Multiple-Nozzle Carburetors. Another development brought about by this demand for rapid acceleration, coupled with great maximum capacity, has been the swing toward multiple nozzles. As has been pointed out on previous pages, there are a number of carburetors now with two nozzles.

Stromberg Carburetors. Fig. 81 shows a cross-section of the Stromberg Model "L." Except that Model "LB," which is shown in Fig. 84, has a horizontal outlet which necessitates the air entering from the top and downward, instead of the side and upward, these two are almost identical, and the general instructions which follow will cover both. In general, all the Stromberg carburetors are of the so-called plain tube type, that is, the air and gasoline openings are plain tubes and thus fixed in size. This construction automatically meters the fuel by the suction of air velocity past the jets, and in addition does away with the auxiliary air valve, all the air supply being taken in through a single pipe which is heated. Thus, the entire air supply is heated, this making for more efficient operation with the present heavier fuels.

The Model "M" is a vertical, and "MB" horizontal form which are similar to the "L" and "LB" models except that they are made without the economizer attachment. This alters their outward appearance, cross sections, and eliminates one adjustment. That is, the "L" and "LB" have three adjustments, high, low, and economizer, while the "M" and "MB" have but two adjustments, high and low. To make these points plain in the subsequent adjustment instructions, Model "MB" is shown in Fig. 85.

General Instructions. The high speed is controlled by the knurled nut "A," which locates the position of the needle "E," past whose point all the gasoline is taken at all speeds. Turning nut "A" to the right or clockwise raises the needle "E" and gives more fuel; turning it to the left or counterclockwise gives less fuel on the "L" and "LB" models. On the "M" and "MB" the instructions are the same except that turning to the left or counterclockwise gives more fuel and to the right less.

If an entirely new setting becomes necessary, put the economizer "L" in the fifth notch (farthest from the float chamber)

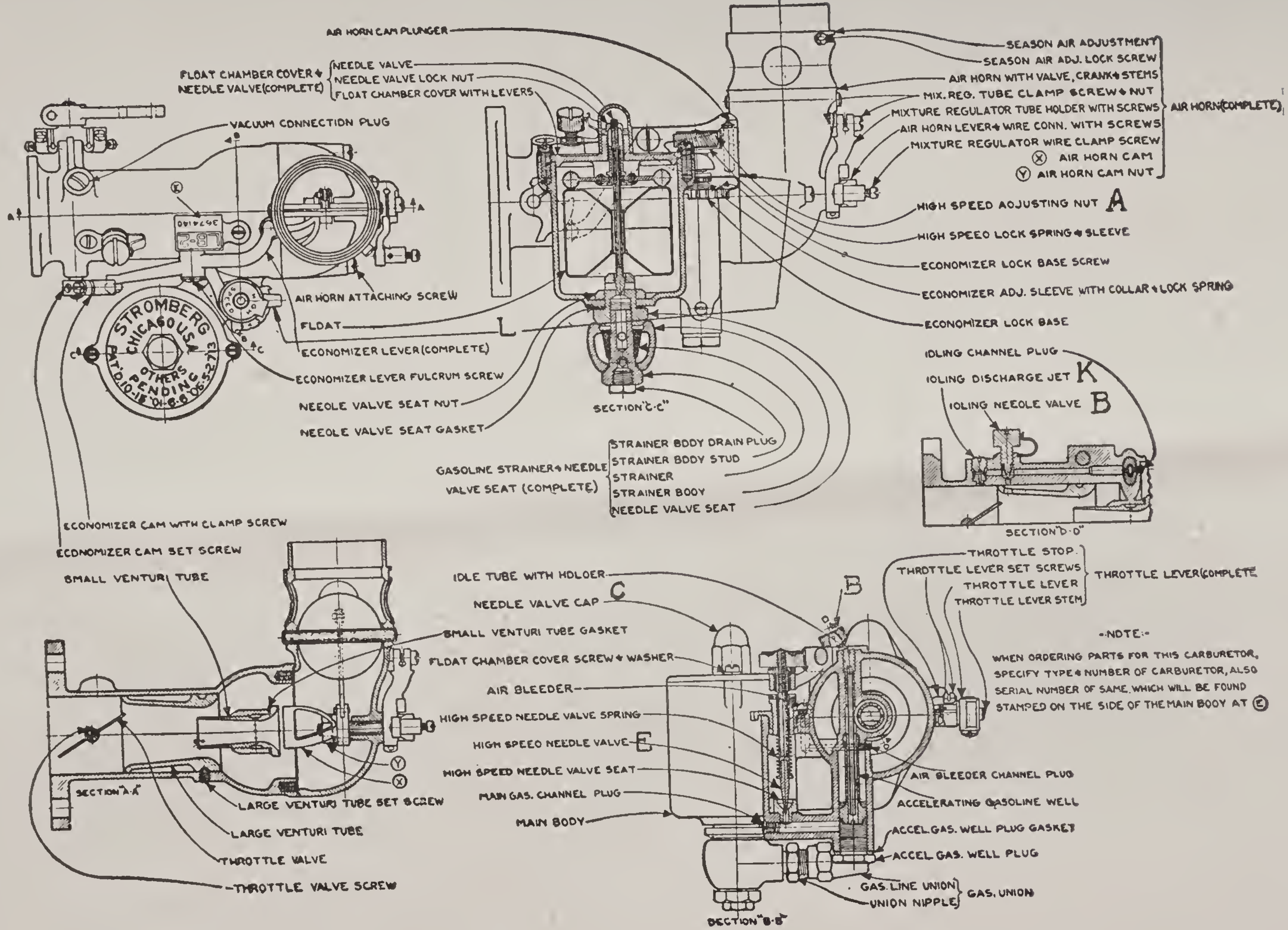

AIR HORN CAM PLUNGER
FLOAT CHAMBER COVER & NEEDLE VALVE (COMPLETE)
NEEDLE VALVE
NEEDLE VALVE LOCK NUT
FLOAT CHAMBER COVER WITH LEVERS
VACUUM CONNECTION PLUG
SEASON AIR ADJUSTMENT
SEASON AIR ADJ. LOCK SCREW
AIR HORN WITH VALVE, CRANK & STEMS
MIX. REG. TUBE CLAMP SCREW & NUT
MIXTURE REGULATOR TUBE HOLDER WITH SCREWS
AIR HORN LEVER & WIRE CONN. WITH SCREWS
MIXTURE REGULATOR WIRE CLAMP SCREW
Ⓧ AIR HORN CAM
Ⓨ AIR HORN CAM NUT
AIR HORN (COMPLETE)
HIGH SPEED ADJUSTING NUT A
HIGH SPEED LOCK SPRING & SLEEVE
ECONOMIZER LOCK BASE SCREW
ECONOMIZER ADJ. SLEEVE WITH COLLAR & LOCK SPRING
ECONOMIZER LOCK BASE
AIR HORN ATTACHING SCREW
FLOAT
L
ECONOMIZER LEVER (COMPLETE)
ECONOMIZER LEVER FULCRUM SCREW
NEEDLE VALVE SEAT NUT
NEEDLE VALVE SEAT GASKET
STROMBERG CHICAGO U.S.A. PAT'D. 10-18-'04-6-6-'06-5-2-'13 OTHERS PENDING
SECTION "C-C"
IDLING CHANNEL PLUG
IDLING DISCHARGE JET K
IDLING NEEDLE VALVE B
SECTION "D-D"
GASOLINE STRAINER & NEEDLE VALVE SEAT (COMPLETE)
STRAINER BODY DRAIN PLUG
STRAINER BODY STUD
STRAINER
STRAINER BODY
NEEDLE VALVE SEAT
ECONOMIZER CAM WITH CLAMP SCREW
ECONOMIZER CAM SET SCREW
SMALL VENTURI TUBE
IDLE TUBE WITH HOLDER
NEEDLE VALVE CAP C
SMALL VENTURI TUBE GASKET
FLOAT CHAMBER COVER SCREW & WASHER
AIR BLEEDER
HIGH SPEED NEEDLE VALVE SPRING
HIGH SPEED NEEDLE VALVE E
HIGH SPEED NEEDLE VALVE SEAT
MAIN GAS. CHANNEL PLUG
MAIN BODY
B
THROTTLE STOP
THROTTLE LEVER SET SCREWS
THROTTLE LEVER
THROTTLE LEVER STEM
THROTTLE LEVER (COMPLETE
-NOTE:-
WHEN ORDERING PARTS FOR THIS CARBURETOR, SPECIFY TYPE & NUMBER OF CARBURETOR, ALSO SERIAL NUMBER OF SAME, WHICH WILL BE FOUND STAMPED ON THE SIDE OF THE MAIN BODY AT Ⓔ
AIR BLEEDER CHANNEL PLUG
ACCELERATING GASOLINE WELL
ACCEL. GAS. WELL PLUG GASKET
ACCEL. GAS. WELL PLUG
GAS. LINE UNION
UNION NIPPLE
GAS. UNION
SECTION "B-B"
SECTION "A-A"
Ⓨ
Ⓧ
LARGE VENTURI TUBE SET SCREW
LARGE VENTURI TUBE
THROTTLE VALVE
THROTTLE VALVE SCREW

Fig. 84. Stromberg Model "LB" Horizontal Type Carburetor
Courtesy Stromberg Carburetor Company, Chicago

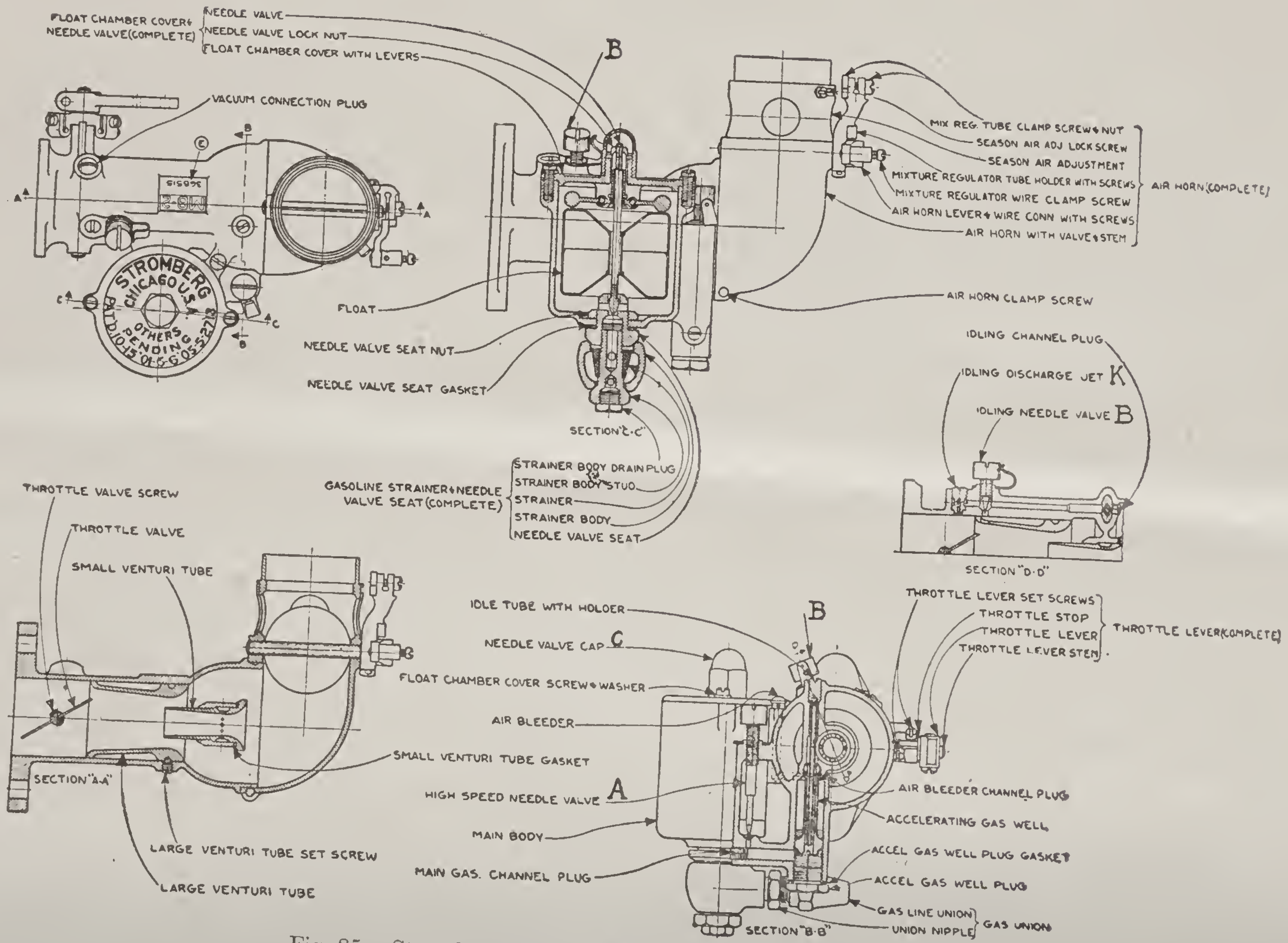


Fig. 85. Stromberg Model "MB" Horizontal Type Carburetor
Courtesy Stromberg Carburetor Company, Chicago

as an indicator, then turn the nut "A" to the left until the needle "E" reaches its seat as shown by the nut not moving when the throttle is opened and closed. When the needle "E" is in its seat it can be felt to stick slightly when nut "A" is lifted with the fingers. Find the adjustment of "A" where it just begins to move with the throttle opening, then give it 24 notches to the right or clockwise. In this turning the notches can be felt. Then move the economizer pointer "L" back to the zero (0) notch, toward the float chamber which will give a rich adjustment. Warm the motor thoroughly, then thin down the mixture by turning "A" counterclockwise until the motor shows the best power with a quick opening of the throttle. This will be the desired adjustment.

The low speed adjustment is made by means of the adjusting screw "B," which controls the jet "K." The latter passes the gasoline in above the throttle and the movement of "B" provides the necessary air dilution. Screwing "B" in clockwise gives more fuel on all models; outward, less. The best adjustment is usually $\frac{1}{2}$ to 3 turns outward from a seated position. This, it should be noted, is only an idling adjustment and does not affect the mixture above a car speed of 8 miles per hour. When the motor is idling properly, there should be a steady hiss in the carburetor; if there is a leak anywhere, or one cylinder leaks, or if the adjustment is entirely too rich, the hissing sound will be unsteady. The adjustment process should be continued until a steady hissing sound is produced, for best all-around results.

As pointed out previously, Models "L" and "LB," Figs. 81 and 84, have an additional adjustment called the economizer. This tends to the use of a leaner mixture, that is, economy of fuel, hence its name. To give this desired result, high speed needle "E" and nut "A" are raised slightly, the amount of movement being regulated by the pointer "L." After making the high speed adjustment for best power with "L" in the zero (0) notch, as described previously, place the throttle lever on the steering wheel in a position giving about 20 m.p.h. road speed. Then move the pointer "L" clockwise or away from the float chamber, slowly and one notch at a time, until the motor begins to slow down. At this point turn back one notch, that is, the adjustment should be one notch before the point of slowing down.

The amount of this economizer action depends upon the quality of fuel, which differs in different parts of the country, and also varies with the temperature. Thus, in the Middle West the best economizer adjustment will be the third or fourth notch, usually. With Pennsylvania gasolines and throughout the South, the second notch will prove the best adjustment, while on the Pacific Coast no economizer action will be necessary unless distillate is used. Fewer notches of economizer action will be needed in summer than in winter.

Zenith Carburetors. The Zenith Model "O" carburetor, shown in Fig. 83, enjoys wide use in this country because of its simplicity. It has fewer ordinary adjustments than any other carburetor. This is so constructed that but one adjustment, that for slow speed, is provided. However, its makers realize that sometimes changes and adjustments are necessary to secure proper results. They provide for these by the removal of three internal parts and their replacement with simpler parts, but with different working orifices, or holes.

Zenith Adjustments. The three parts mentioned are: choke tube, main jet, and compensator. In Fig. 83, the choke tube is marked *X*. This is really an air nozzle of such a stream-line shape (approximating the Venturi) as to allow the maximum flow of air without eddies and with the least resistance. When the pick-up, or acceleration, is defective and slow-speed running is not smooth, the choke tube is too large. In this case, it will be found that a larger compensator *I* does not better the situation. Then a smaller choke tube is needed. This is held in place by a screw X_1 in the choke itself with a lock washer to prevent its jarring loose. To remove the choke, the butterfly *T* must first be removed. In the horizontal types, the body is in two pieces, which are held together by an assembling nut. When this is removed and the two pieces taken apart (the bowl from the barrel), the choke can easily be slipped out of the barrel. When the motor will not take a full charge, that is, when it cannot, with the throttle fully opened, this indicates the need for a larger choke tube. It will be noted that although the pick-up is good, the car will not make all the speed of which it is capable. In this case, take out the choke tube *X*, as explained above, and replace with a larger one.

Changing the Main Jet. The main jet *G*, Fig. 83, shows its influence mostly at high speeds. When running at high speed on a level road, if the indications show a rich mixture, irregular running, characteristic smell of over-rich mixture from the exhaust, firing in the muffler, sooting up of the spark plugs, and low mileage, the main jet is too large and should be replaced by a smaller one. On the other hand, when running at high speed, if the indications are that the mixture is too lean, if the car will not attain its maximum speed, if there is occasional back firing at high speed, then the main jet is too small and should be replaced by a larger one. In respect to back firing, however, care should be used, as this is more often due to large air leaks in the intake or valves or to defects in the gasoline line.

To Replace Main Jet. When it is necessary to change the main jet *G*, Fig. 83, to a larger or smaller size, the lower plug *L* is removed first. This has a square head and is removed with a wrench. Then the main jet is unscrewed from below by means of a screwdriver, a notch being cut into its lower part for this purpose. In reassembling care should be taken to see that the fiber joint packing is on the jet and that the jet is screwed up far enough to compress this. Otherwise gasoline may leak around the threads. But one fiber washer should be used. Then the lower plug *L* is replaced, and this also must be screwed up tight.

Changing the Compensator. The third change which can be made is in the compensator *I*, Fig. 83. The opening in this supplies the fuel to the secondary well and, if too large or too small, will have a corresponding influence upon the running of the car. The makers call attention to the fact that its influence is most marked at low speeds and suggest that when this is suspected, the car should be tried out on a hill, regular but long, and of such a slope that the motor will labor rather hard to make it on high gear. Under such a test, if the indications are of too rich a mixture, that is, the same as for a rich mixture at high speed on the level, as previously explained, the compensator is too large, and must be replaced with a smaller one. If the indications are of a lean mixture, with the motor liable to miss and give a jerky action, the compensator is too small and must be replaced with a larger one. This is easily removed in the same manner as the main jet *G*, by removing the bottom plug beneath it and then removing *I* with a screwdriver, through the medium of slots for this purpose in its lower surface. In connection with this last method of adjustment, the makers recommend that the workman should start with the setting provided, then proceed to determine first the main jet, then the compensator, then the choke. In a sense, this method makes double work, for any change in the choke calls for a corresponding change in the main jet, but it gives superior results.

Slow-Speed Adjustment. The one adjustment in the Zenith device which is really an adjustment and not a change is that for slow speed. This is preferably made on the garage floor, with the motor properly warmed up. When this has been done and it has been throttled down to idling speed, any irregularity, such as the lack of ability to throttle down to a really slow speed (say 350 or less r.p.m.), calls for a change in the adjustment. When the throttle *T*, Fig. 83, is nearly closed, there is considerable suction at the edge, and the tube *J* in the top of the secondary well *P* terminates in a hole *A* near the edge of the butterfly at which gasoline is picked up. If the motor will not throttle down as slowly as it should, the supply of gasoline can be reduced by means of the external milled screw *O*. When this is turned in, the air entrance *N* is restricted, and consequently a richer mixture is drawn in. When it is unscrewed, or turned out, a larger air opening is uncovered, and consequently a leaner mixture is drawn in.

In this connection, many factors other than the correct slow-speed adjustment of the carburetor may prevent good idling. Some of these are: too light a flywheel, too much spark advance, and air leaks created by (1) poor gaskets, (2) loose valve stems, (3) pitted or scored valves, (4) leaky valve caps, (5) spark or valve plugs, (6) leaky priming cups, and others. Obviously, if any of these faults exist, no amount of adjustment of the slow-speed device on the carburetor will give good idling.

Horizontal Type Adjustments and Changes. Everything that has been said thus far applies equally well to the horizontal type shown in Fig. 86, except for the adjustment of the idling jet. In this form, the idling jet P_2 is supported by the knurled nut *O* which governs the air opening for this jet, and replaces the horizontal milled screw *O*. If a leaner mixture is desired, this is turned to the right, or clockwise; this lowers the jet and increases the size of the available air passage. For a rich mixture it is turned the other way, or counter-clockwise, reducing the air opening.

Float Removal. In both models, it will be noted that the float cover is held on by the spring catch. This is lifted by means of its handle, and swung around out of the way. The float cover can then be lifted readily by means of the knurled edge. When this is removed it should be lifted up straight. The float is then exposed and can be removed easily with a piece of wire bent at the end or with a match inserted in the center hole.

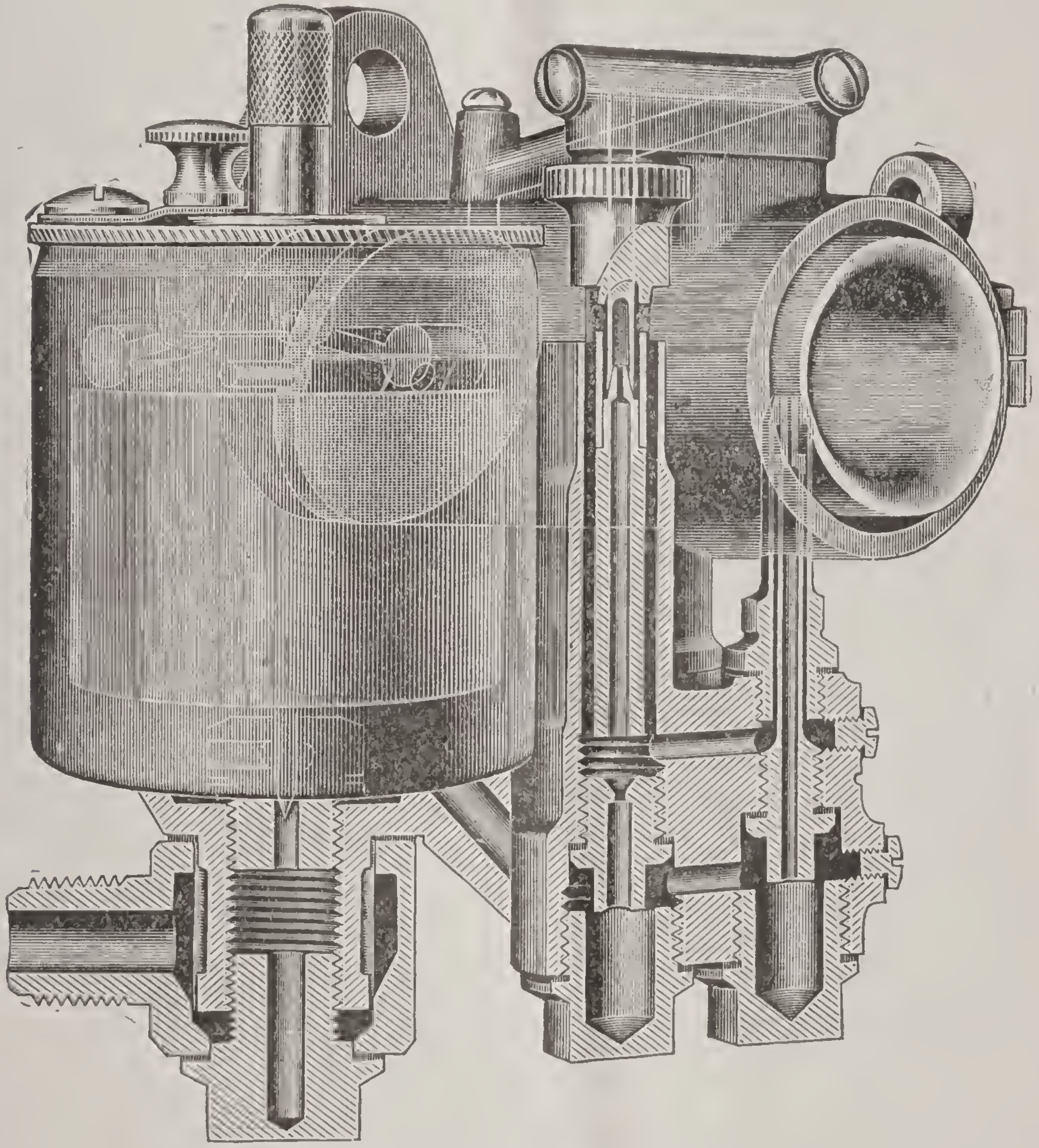


Fig. 86. Zenith Carburetor, Model "HP"
Courtesy of Zenith Carburetor Company, Detroit, Michigan

Duplex Model Adjustments. The Duplex model, known as Model "OD", is shown in Fig. 87. Although this is an external view, it indicates the construction, and it will explain the adjustments readily. This has a single float chamber, shown at the left, and a single air inlet joined to two separate and distinct spray nozzles, with separate Venturis and idling adjustments. The vaporizing chambers, or carburetor barrels, are arranged side by side, and the throttle valves are mounted on the same shaft and work in unison. The device is intended for eight- and twelve-cylinder motors and is rigged up generally with a pair of separate inlet manifolds, one for each group of cylinders.

Adjustments. The adjustments on this double Model "O" are the same as on the single Model "O". It will be noted that the slow-speed adjustments are through milled headed screws *O*. One of these projects horizontally on each side, the same as on the single model. To make this adjustment, the motor should be started and warmed up; then the spark plugs on one group of cylinders are disconnected and the slow speed adjusted for the other set. Then the process is reversed, with the other set of plugs disconnected, and the second group of cylinders adjusted.

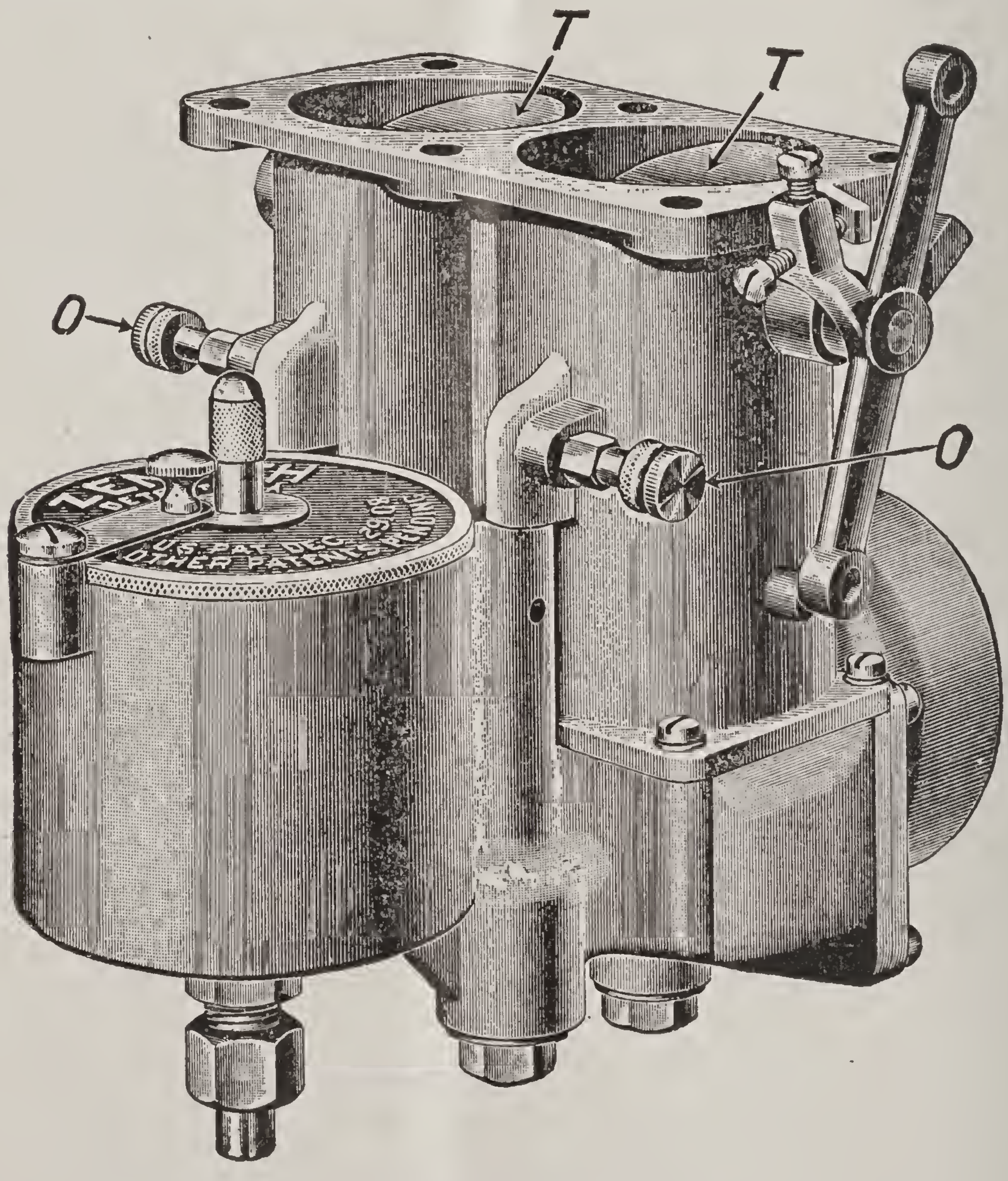


Fig. 87. Zenith Carburetor, Duplex Model "OD"
Courtesy of Zenith Carburetor Company, Detroit, Michigan

As the adjustment is changed, a difference in the idling should be noticed. If the motor begins to run evenly or speeds up, it shows that the mixture becomes right in proportion, but that there is too much of it. This is remedied by changing the butterfly throttle position slightly, closing it by screwing out the stop screw which regulates the closed position for idling. Care should be taken to have the butterfly held firmly against this stop at all times when idling the motor. If the single group of cylinders being adjusted seems to run irregularly after changing the position of the butterfly, another adjustment of the knurled screw *O* may have to be made. After one group of cylinders has been made to idle satisfactorily, the same procedure should be repeated with the other group, that is, each half of the motor should be adjusted for idling independently to about the same speed. The single thing which is radically different and must be remembered in this connection is that multi-cylinder engines have very light flywheels and reciprocating parts, so the motor is extremely sensitive at low speeds to unequal conditions of ignition, compression, and air leaks. This makes it more necessary than with a plain four- or six-cylinder form to have the motor in the best possible condition before changing the carburetor idling adjustment.

The Zenith Model "L" is a refinement of Model "O," just described, but all adjustments are made in the way described for "O."

Carburetors on Ford Cars. On the Model "T" Ford car, there are two very simple forms of carburetor used. They are very much alike in general design and construction, but they are made by different firms. The form shown in Fig. 89 is the Model "G" Holley, while the other form, shown in Fig. 88, is the Kingston. Both forms have been used in about equal quantities by the Ford Company from 1909 to date.

In the Kingston (Fig. 88), "A" is the fuel connection, "B" the air valve, "C" the low speed tube, "D" the spray nozzle, "E" the choke throttle, "G" the drain cock, "H" the lever operating the choke throttle, "J" the needle valve, and "K" the needle valve binder nut. To adjust, warm up the motor, retard the spark fully, open the throttle five or six notches on the steering post quadrant, then loosen the binder nut "K" so the needle valve "J" turns easily. Turn this valve down with the dash adjustment, until it seats lightly but do not force it. Then turn back away from the seat one complete turn. Let motor run a little while, then make the final adjustment. Close the throttle until the motor runs at idling speed, which can be controlled by adjusting the stop screw in the throttle lever. Adjust the needle valve "J" towards its seat slowly until the motor begins to lose speed. Stop and adjust the needle valve away from its seat very slowly until the motor attains its best and most positive speed. Close the throttle until the motor runs slowly, then pull it open quickly. The motor should respond strongly. If sluggish, a further adjustment may be necessary. Tighten the binder nut.

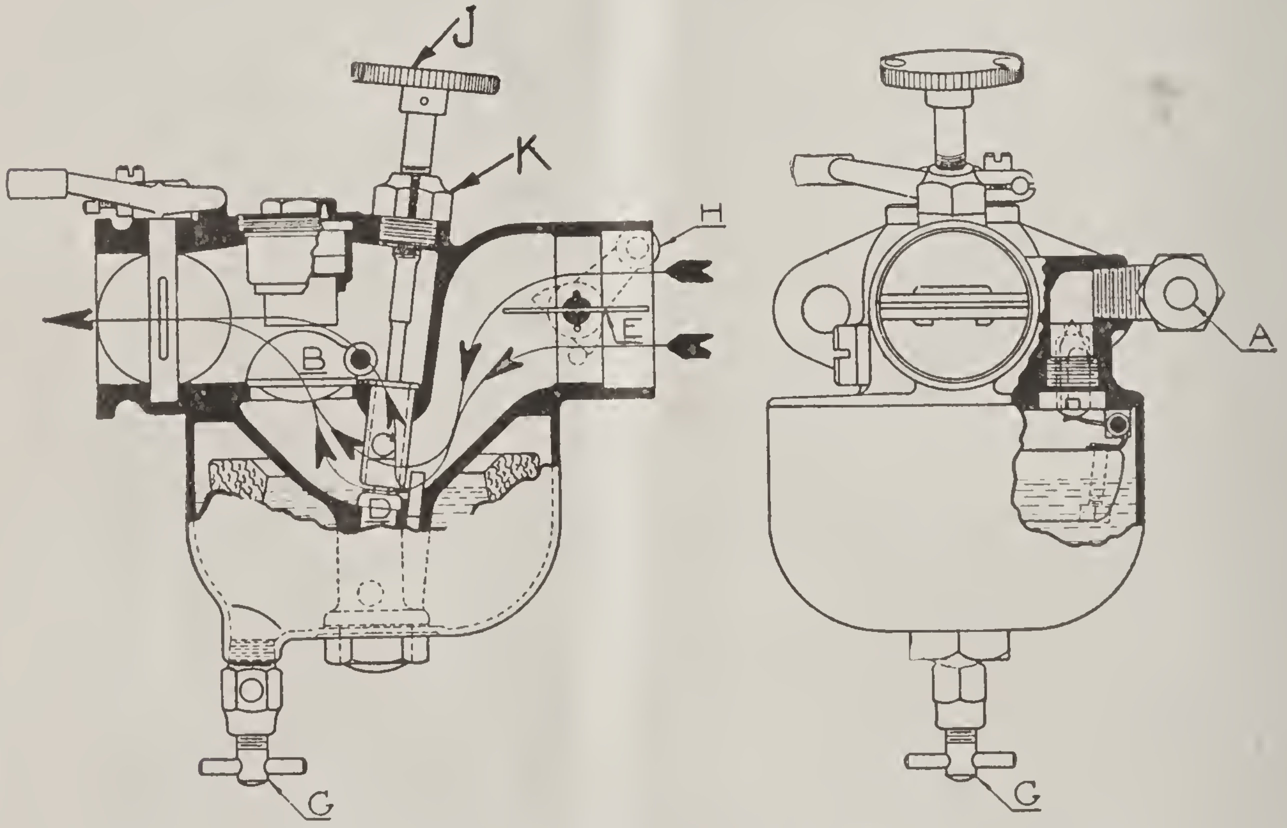


Fig. 88. Drawings Showing Construction of Kingston Model "L2" Carburetor
Courtesy Byrne, Kingston and Company, Kokomo, Indiana

In the Holley, *A* is the thumbscrew with an extension to the clutch, by means of which the needle valve *B* is raised or lowered. The lower end of this projects down into the spray nozzle *C*, where fuel enters from the float chamber *D*, reaching it through the gasoline intake *E*. To draw off sediment and water use the cock *F*.

From the nozzle, the fuel passes up through the strangling tube *G*, where it is met by the entering air from the air inlet *H*, which has been deflected downward and toward the center of this circular space so as to pick up the spray of fuel at the nozzle and carry it upward in the strangling tube. Then it passes into the mixing tube *N*, thence out to the motor via the mixture outlet *I*. In this, its quantity is governed by the throttle, the lever of which may be seen at *J*. In the air intake, there is a throttle plate *K*, which deflects a large part of the entering air so that it passes to the right (straight in) and is added to the mixture in the mixer chamber. This forms the auxiliary air valve. The position of this plate, governed by the auxiliary throttle lever *L*, determines the quantity of both the primary and auxiliary air, since by its position it splits the entering air into two parts, one of which becomes the primary air, and the other the auxiliary air. For low speeds and idling, the low-speed tube *M* carries the very rich mixture up direct to the mixing chamber and thus into the engine.

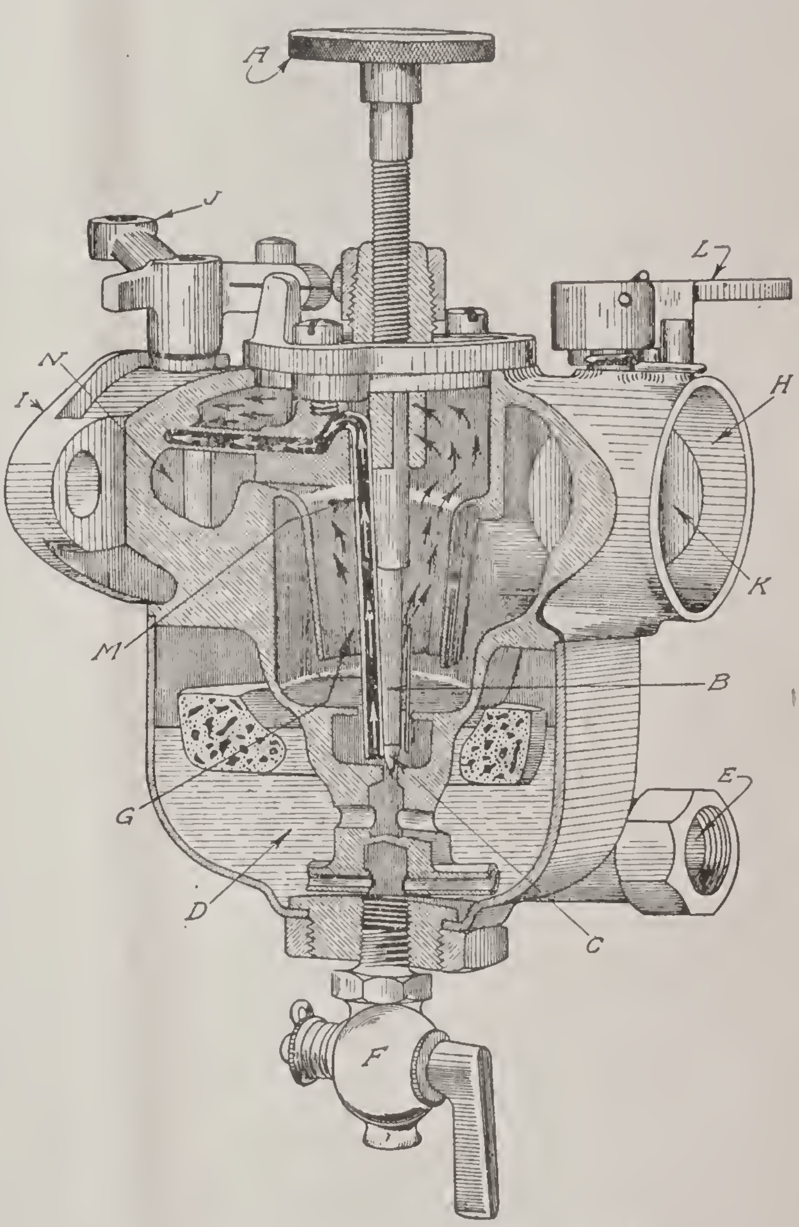


Fig. 89. Section of Holley Carburetor for Ford Cars
Courtesy of Holley Brothers Company, Detroit Michigan

Ford Adjustment. This Holley model, like the Kingston, has but one adjustment. The needle valve *B*, which has a projecting knurled head *A* for turning it, has a conical point *C* which seats into the fuel opening. If this is seated, no gasoline can enter, but as it is screwed out or up an opening is created and increased, which allows fuel to flow. The amount of this determines the amount of mixture entering the cylinder combustion chambers. Consequently, the primary adjustment with this screw is that of the fuel flow. Air enters through the opening *H*, passes the throttle *K*, and then mixes with the fuel spray, diluting it and carrying it up into the cylinders. The amount of the air is governed by the air lever *L*, its position being adjusted at the factory. The adjustments as recommended by the Ford Motor Company are as follows:

Initial Adjustment. The usual method of regulating the carburetor is to start the motor, advance the throttle lever (on the steering wheel) to about the sixth notch, with the spark lever (also on the steering wheel) retarded to about the fourth notch. The flow of gasoline should now be cut off by screwing the needle valve down (to the right) until the engine begins to misfire; then gradually increase the gasoline feed by opening the needle valve until the motor picks up and reaches its highest speed and until no trace of black smoke comes from the exhaust. Having determined the point where the motor runs at its maximum speed, the adjustment should not be changed except as indicated below. For average results, a lean mixture will give better results than a rich one.

Dash Adjustment. The gasoline adjustment is placed on the dash, Fig. 90, the milled head shown being fastened to a long rod whose lower end is attached to the needle valve head *A*, Fig. 89. Any movement of the milled head moves the needle valve and gives more or less gasoline. After the car has been worked in so that it runs satisfactorily, a file mark should be made on the face of this milled head to indicate the point at which the engine runs most satisfactorily. This is indicated by Fig. 90, in which *A* shows the milled headed rod projecting through the dash, and *B* the mark for satisfactory normal running. In cold weather, it will probably be found necessary to turn the finger wheel one-quarter turn to the left, or counter-clockwise, as shown at *C*, particularly in starting a cold engine. This movement increases the amount of gasoline and makes the mixture richer. In warm weather, gasoline vaporizes more readily, and it will be found advisable to give the milled head a one-quarter turn to the right, or clockwise, about as shown at *D*. This admits less gasoline and gives a leaner mixture. This last adjustment is particularly advisable when taking long rides at high speed for it increases the mileage per gallon of fuel.

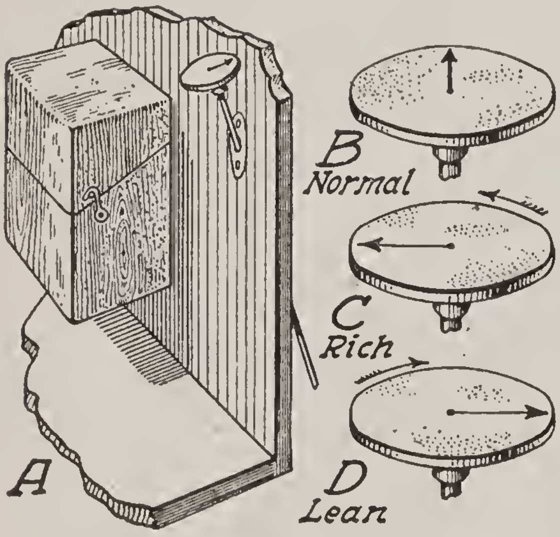


Fig. 90. Dash Adjustment of Ford Carburetor
Courtesy of Ford Motor Company, Detroit, Michigan

Other Ford Models. While the foregoing describes the carburetors used by the Ford Motor Company, there have been many different carburetors developed by other companies intended to replace the ones just described and supposedly giving better results. Practically every large carburetor company has a so-called Ford model, while many firms build only carburetors for Fords. From which it may be argued backwards that the results obtained with the cars as sold are not always entirely satisfactory. A few of these carburetors will be described although lack of space prevents a description of many of them.

Stromberg Ford Model. Fig. 91 shows the Stromberg Ford Model, this attaching to the engine in the same way and with the same bolts as the regular device, but having a vertical air inlet pipe to which a hot air stove and pipe bring heated air from the regular exhaust manifold above, down into the carburetor. Aside from this difference, this carburetor provides an additional adjustment for the air, and for this purpose a lever is provided which clamps around the steering post, this having a wire connection to the air valve in the carburetor. The adjustment of this device is very similar to the adjustment of the other Stromberg models, previously described. The high speed adjusting nut is marked *A* and the low speed adjusting screw *B* to correspond with those. The same instructions will apply to this, in that it is like the "M" models, turning the high speed nut to the left or counterclockwise gives more fuel and to the right less. For an entirely new setting of this Ford model an opening of 12 notches back from a seated position is recommended.

Toquet Ford Atomizer. An entirely different principle of fuel vaporization is used in the Toquet carburetor for Fords, this being a very small device, especially designed for, and built only for the Ford car. It is shown in section in Fig. 92, this presenting also the method of operation. The carburetor consists simply of a long air passage in which throttle lever, air control throttle, needle valve and atomizer are all placed, and to one side of this the simple float chamber.

In the sketch Fig. 92, air enters at the right, passing the choke throttle, and then the needle valve *A*. This is surrounded by a sleeve full of small holes into which the air is forced, then

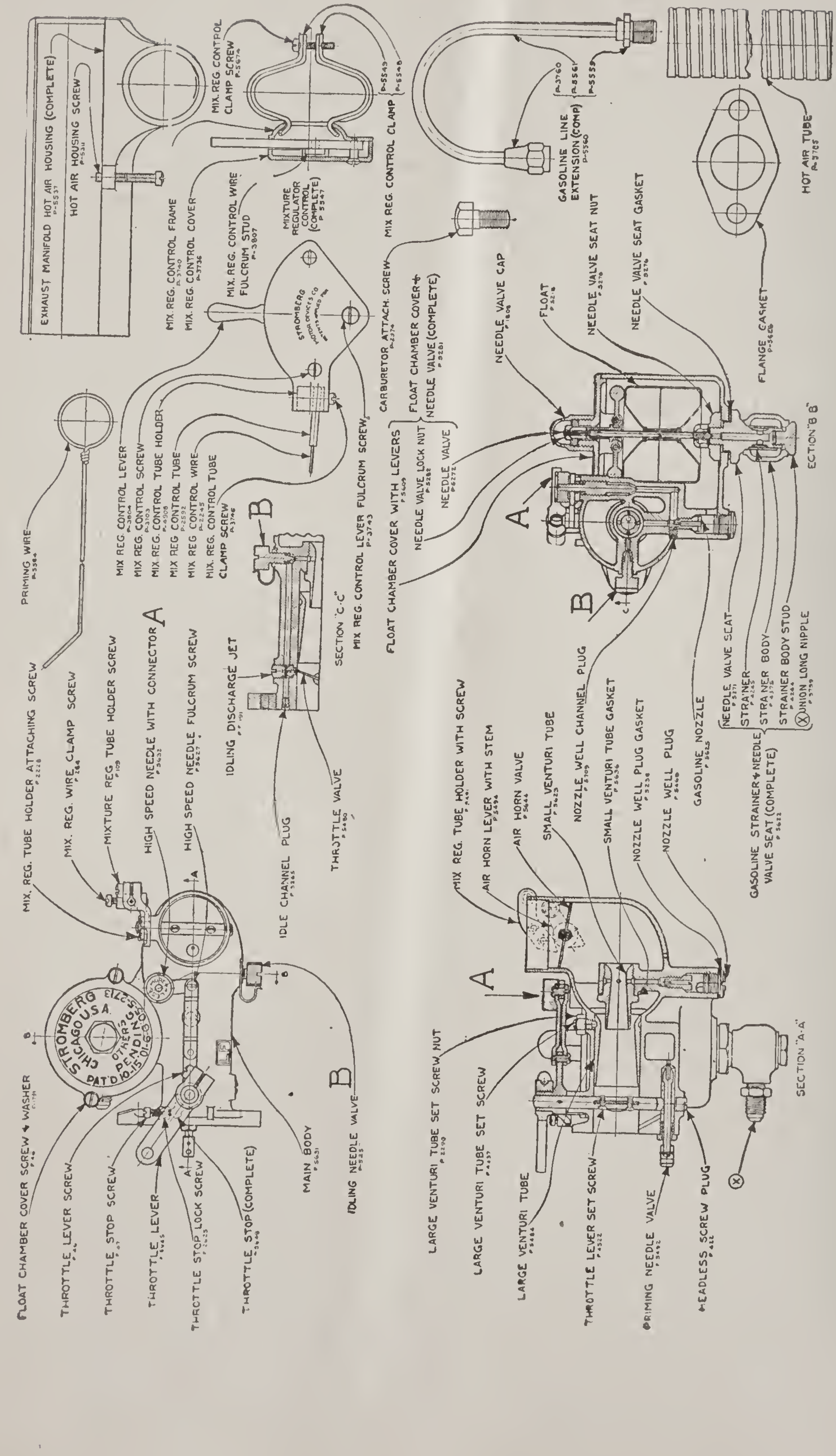


Fig. 91. Drawings of Stromberg Ford-Model Carburetor
Courtesy Stromberg Carburetor Company, Chicago

passes downward carrying gasoline with it to the fuel channel *B* at the bottom, and thence into the atomizer *C*. Additional air enters the latter at the top, and these two air supplies, combined with air pressure along the passage tending to suck the gasoline out of the atomizer *C*, thoroughly and wholly atomize the fuel.

There really is but one adjustment, that of the needle valve *A*, made by means of the clamp *E*, which can be connected, if desired so as to be moved by the dash milled head of the Ford.

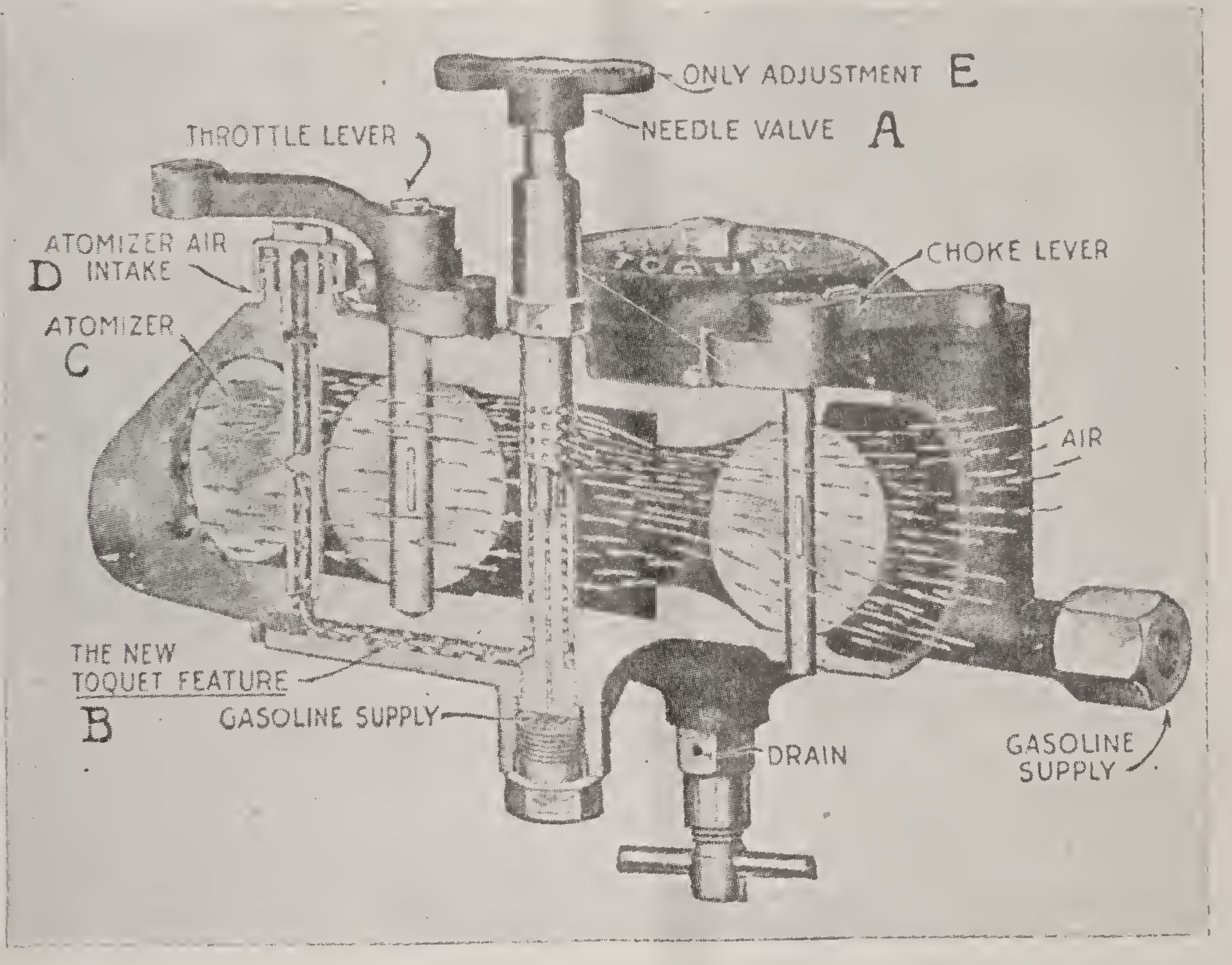


Fig. 92. Extremely Simple Toquet Carburetor for Ford Cars
Courtesy Toquet Manufacturing Company, Westport, Connecticut

When this is done the instructions for adjustment follow those of the Holley or Kingston carburetors just given. Although not provided by the maker for this purpose, it would seem that the secondary air supply, through the atomizer *C*, might be regulated somewhat by means of the atomizer air intake *D*, which screws into place, and consequently can be screwed on or off, more or less, this movement admitting less or more air at the bottom of the intake. Moreover, it is provided with a screwdriver slot to make this easy.

Other Holley Carburetors. As has been stated, the carburetor illustrated in Fig. 89 and just described is a Holley Model "G". This firm also markets a Model "K", which is very similar to the "G", as will be noted in Fig. 93. The biggest differences between these models are: the vertical outlet in place of a horizontal; and the placing of the needle valve at the bottom because of this. In this latter figure, fuel enters by the gasoline pipe through the strainer *A*, past the float valve *B*, into the float chamber *D*, the level being regulated by the movements of the cork float *C*. From there, it passes through the opening *F* into the nozzle well *E*, through the hole *H* past the needle to a level in its cup-shaped upper end which just submerges the bottom of a small tube *J*, with its outlet at the edge of the throttle disc *K*. When the engine is cranked with the throttle nearly closed an energetic flow of air past this point draws liquid fuel which is atomized upon its exit from the small opening at the throttle edge.

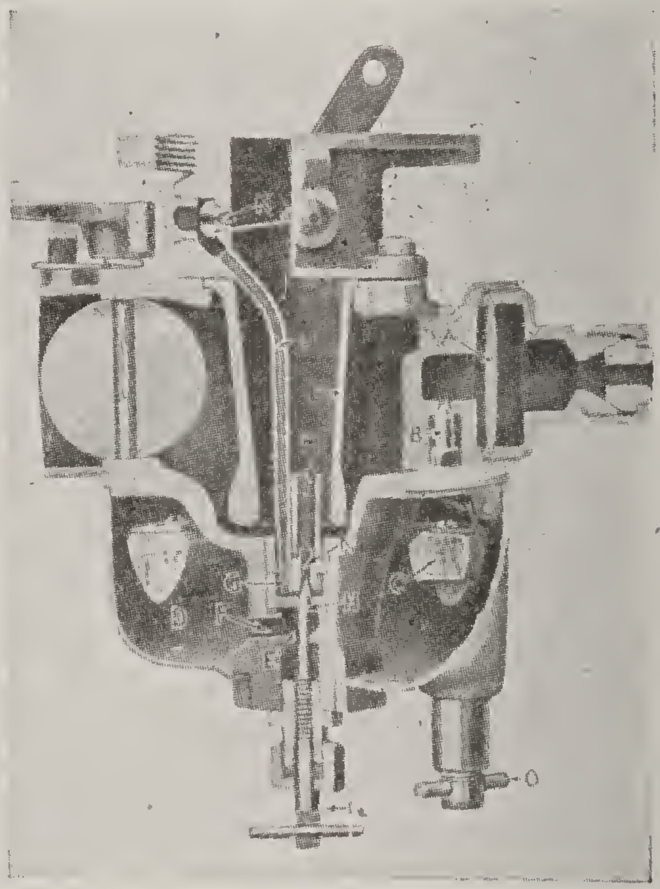


Fig. 93. Holley Curburetor, Model "K"
Courtesy of Holley Brothers Company, Detroit, Michigan

As the engine rotates, considerable air is forced to move through the conical passage outside of the strangling tube *L*. The shape of the passage around the lower end of this is such that the entering air attains its highest velocity, and thus lowest pressure, near the upper end of the standpipe *M*. Consequently, there is a difference in pressure between the top and bottom of this pipe, and the air flows downward through the series of holes *N*. At the bottom it turns sharply upward, picks up the fuel spray there and passes into the main vaporizing chamber above *O*, and thence past the opened throttle into the inlet manifold at *P*.

Adjustment. As will have been noted, there is but one adjustment, that provided by the movement of the needle valve *I*. When this is screwed to the right, or clockwise, the valve moves upward and reduces the size of the fuel opening. When turned backward to the left, or counter-clockwise, it increases the opening and admits more fuel. The effect of these changes in its setting are claimed by the maker to be manifest equally over the whole range of the motor. According to the maker, this desirable feature is the result of utilizing in the nozzle action the pressure drop due to velocity of flow rather

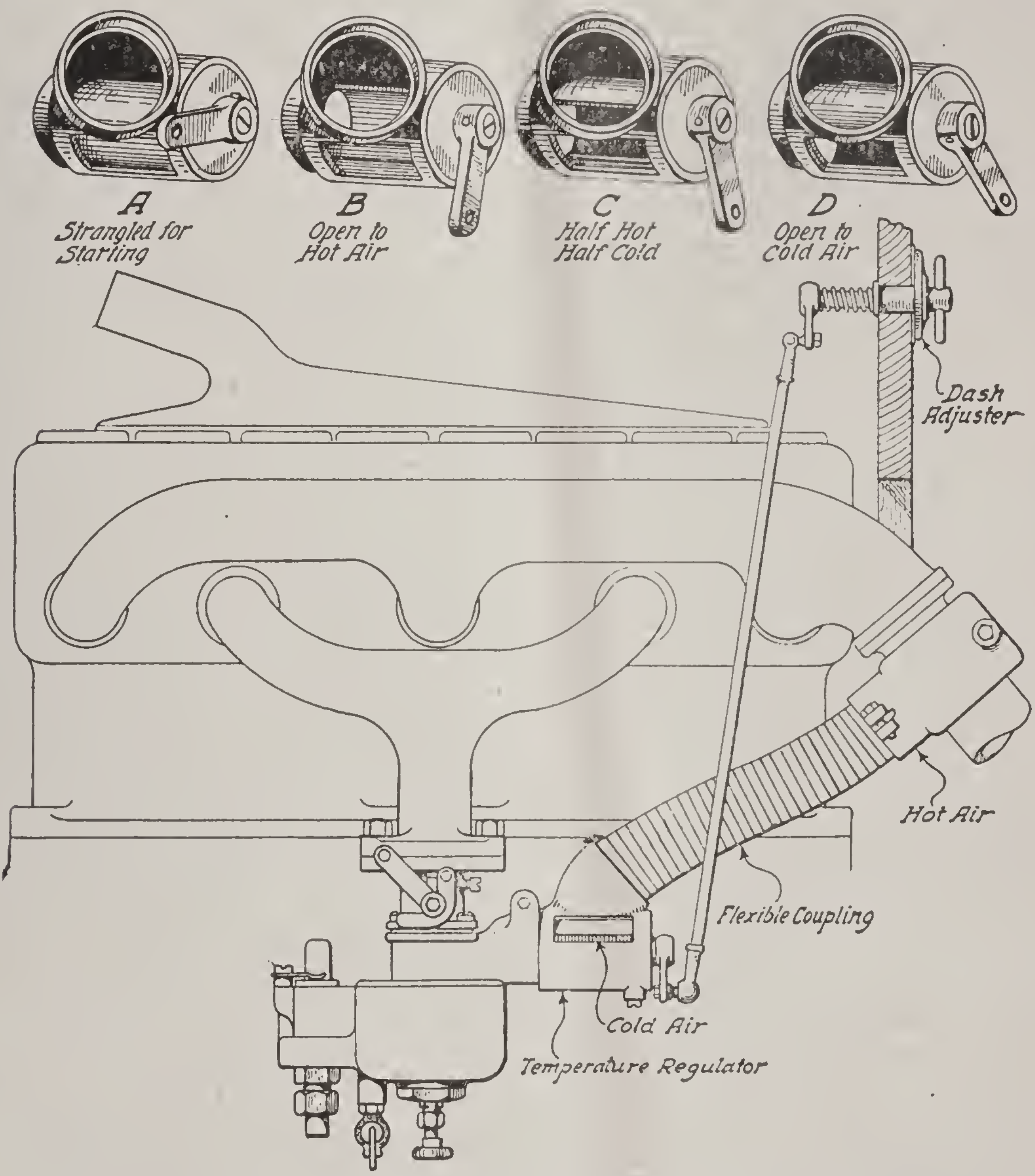


Fig. 94. Holley Temperature Regulator Attached to Carburetor

than the pressure drop causing the air to flow. Other Holley models, for motorcycles and small cars, are smaller in size, and need not be described here.

Temperature Regulator. This firm recommends a temperature regulator for use with its own and other carburetors. This is particularly important now, with the scarcity of fuel, its consequent low quality, and its high price. It is admitted by all that the heat is necessary in cold months, but that it is less necessary, although advisable, in warm months. This necessitates a means of varying it. There is no better source of heat than the handy exhaust pipe where heat is going to waste, so the Holley device, as illustrated in Fig. 94, utilizes the exhaust pipe as a source of heat and leads the same to the carburetor through a flexible tube with a regulating valve at the lower, or carburetor end. This is regulated by a simple rod connection with a small handle which projects through the dash and has a dial behind it. This can also be used as a strangling valve to assist starting, as shown above at *A*, for hot-air supply in winter, as at *B*, for half cold air in the spring and fall months, and for all cold air throughout the summer months.

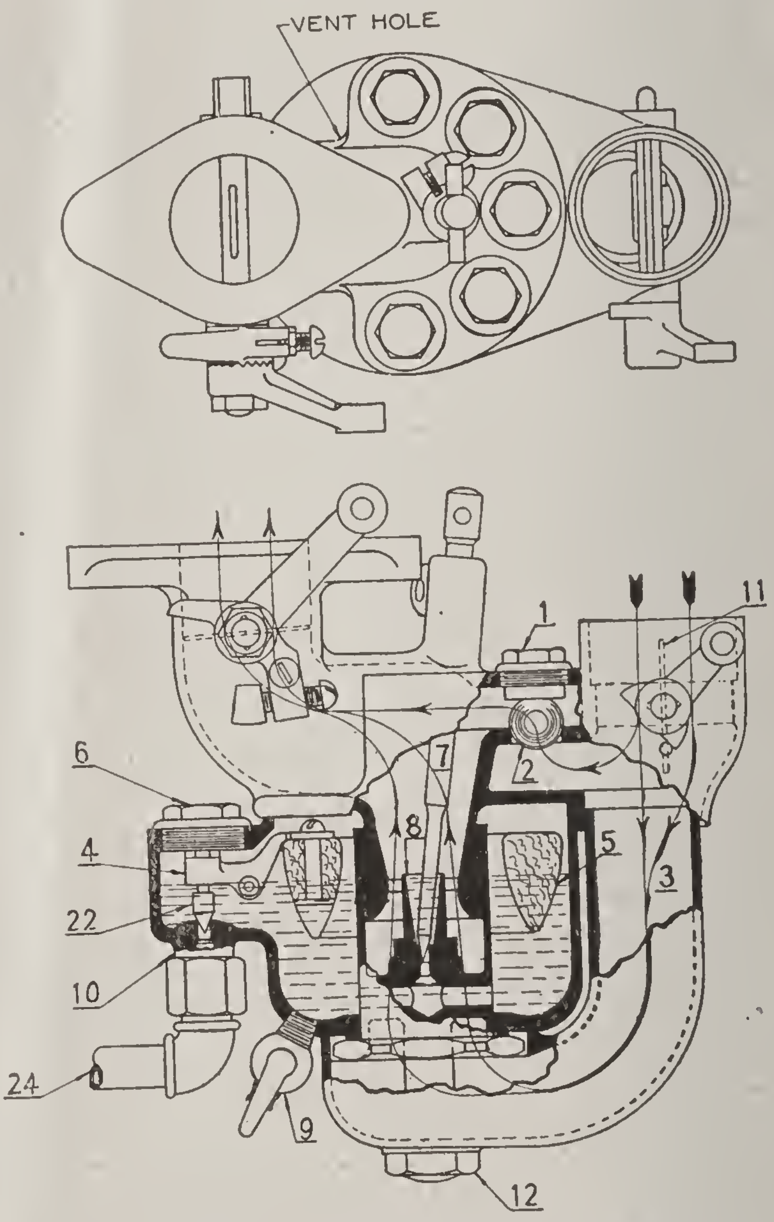


Fig. 95. Plan and Section of Kingston Enclosed Carburetor
Courtesy of Byrne, Kingston and Company, Kokomo, Indiana

Kingston Carburetors. *Enclosed Type.* The Kingston enclosed type, as shown in Fig. 95, differs from the type previously shown in that the auxiliary air valves in the form of various sizes of steel balls are used. These are normally seated, but they are lifted from their seats by increased suction. The primary air valve is not radically different from the former model, but the passage of the air is vertical rather than at an angle. When the suction lifts the ball valves, more air is admitted. This joins the partially vaporized mixture at the top of the vaporizing chamber and completes the vaporization and dilution before passing the throttle valve on its way to the inlet manifold. Like the model previously shown, it has the cup-shaped needle recess, so that when the motor is shut off, a pool of fuel collects there; this makes starting easy, for this fuel is drawn directly in, almost without dilution.

Adjustments. If the float is found to be too high or too low, it can be adjusted readily by bending the float lever to which it is attached. The only other adjustments are: the setting of the throttle which governs the lowest speed, this being accomplished by the screw shown on the throttle-lever arm projection at the left; and the setting of the needle valve for satisfactory high speeds. This is accomplished by unscrewing the cap to which the needle is attached and allowing more fuel to flow. Continue until the highest speed is reached and passed, then turn back until the maximum speed is reached.

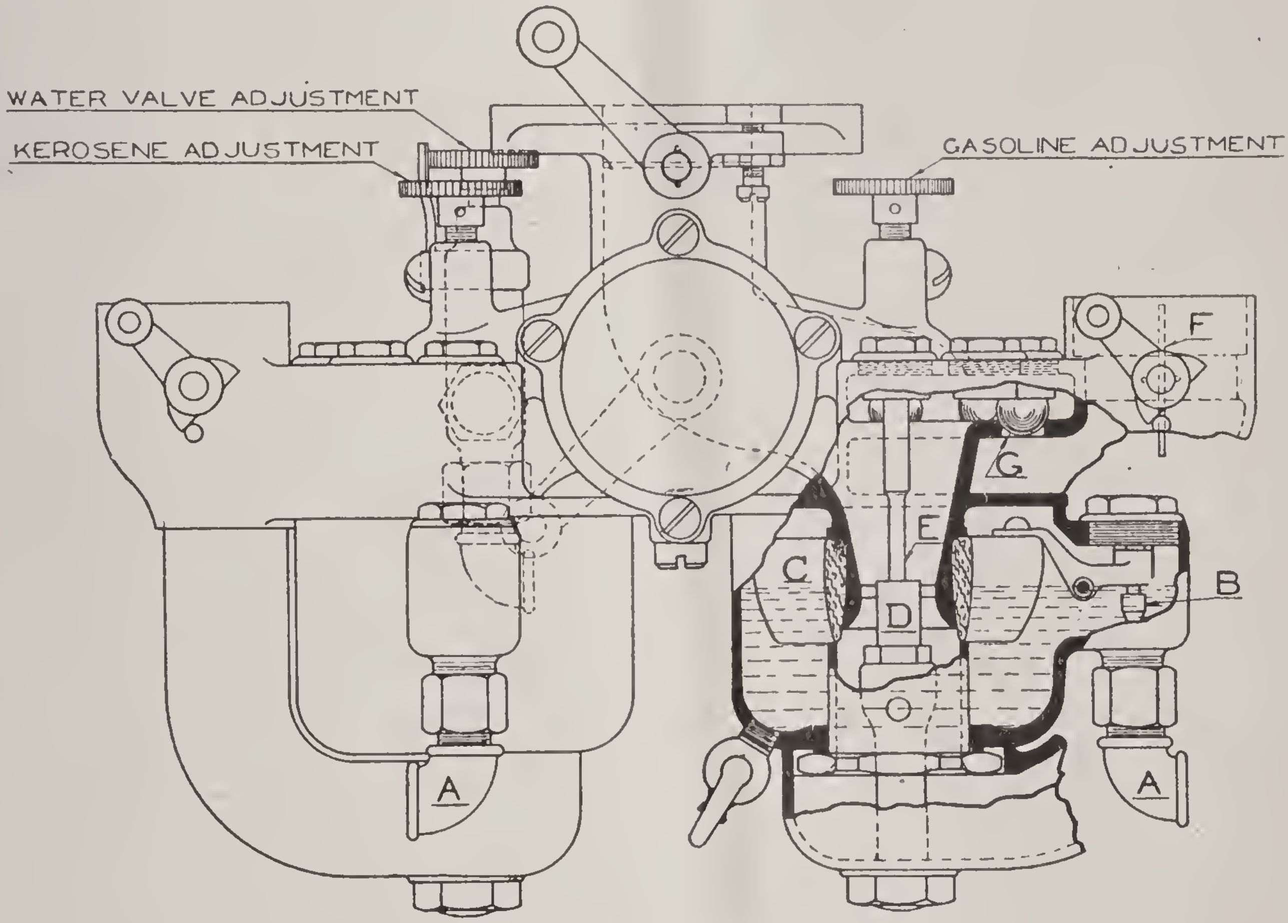


Fig. 96. Part Section of Kingston Dual Form of Carburetor
Courtesy of Byrne, Kingston and Company, Kokomo, Indiana

Kingston Dual Form. This form, as shown in Fig. 96, is really two of the enclosed models, just described, attached to a common outlet and with a single throttle valve. It is intended for use with heavy fuels; one side is connected up for gasoline, which is used in starting and for exceptionally slow speeds long continued, while the other side is set for heavy fuel, such as kerosene, distillate, etc., and is used as soon as the engine running on gasoline has heated up sufficiently. It will be noted that one-half of this device is fitted with a water valve, which is placed on the heavy fuel side. It is a gravity valve seated by its own weight at low speeds and lifted progressively at higher speeds until wide open. In continuous running on heavy fuels, it has been found that after a certain time the engine begins to pound, but that if cooling water be introduced with the mixture, the engine will run cooler, and this pound will disappear. To remedy this is the function of the water valve.

Adjustments. Adjustments and repairs for this model will be exactly the same as with the previously described enclosed model, since it is simply two of these joined together. As has been stated, the added water valve works automatically.

Kingston Model "L." The last Kingston model shown, that of Fig. 97, is very similar to the Ford model, except that it is formed with a vertical outlet, and the air valve *B* added in the vaporizing chamber so formed. This is hinged at the side so as to be swung upward by the suction of the motor, thus uncovering a larger and larger orifice. It is weighted and acts automatically. It will be noted also that the shape of the nozzle has been altered slightly, that on the Ford model being perfectly straight. Near its lower end, it passes through the low-speed tube *C*, which has a series of holes around the bottom and an annular space around the body of the needle. Through this space the fuel and a very little air are drawn for starting, as, at that low suction, the valve *B* would be entirely seated.

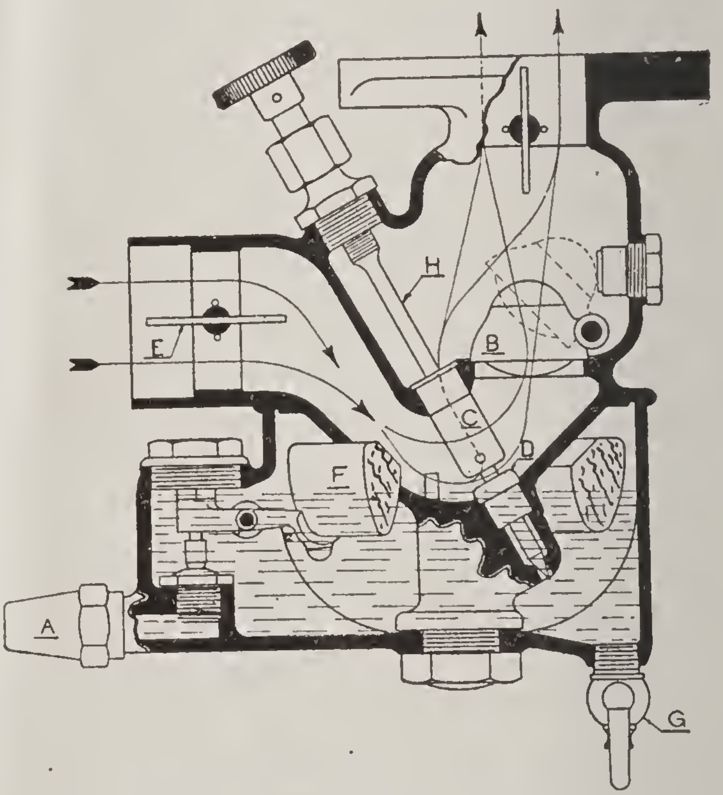


Fig. 97. Section of Kingston Model "L" Carburetor
Courtesy of Byrne, Kingston and Company, Kokomo, Indiana

Adjustments. After retarding the spark, opening the throttle, loosening the needle, and starting the motor, let it run at a fair speed long enough to warm up. Then adjust the needle valve. Close the throttle by adjusting the stop screw in the throttle lever until the motor runs at the desired idling speed. Adjust the needle valve towards the seat slowly until the motor begins to lose speed, which indicates a weak mixture. Now adjust the needle valve away from its seat until the motor attains its best and most positive speed. This should complete the adjustment. Close the throttle and let the motor idle, then jerk it open rapidly. The motor should respond readily. If it does not respond, a slight further adjustment may be necessary. When the adjustment has been made, lock it. Float troubles may be remedied in the same way as for the enclosed model.

Master Carburetor. The Master is called a carburetor without an adjustment. It was originally developed in Los Angeles for the purpose of using the heavy oil, called distillate, which is available there. This, as shown in Fig. 98, is a design of remarkable individuality. Except for the float chamber, it does not resemble any other carburetor. In design it consists of a float chamber to which the fuel enters from below through a round pan-like screen which filters it. From the float chamber the fuel passes through another cylinder-like screen which filters it again. Then it passes to one end of a long fuel passage, from which lead a series of vertical passages, each ending in a nozzle. These passages discharge the fuel into a cylindrical throttle chamber within which is placed a rotary throttle valve. This has a peculiar spiral-shaped edge, so that one tube—the end one shown on the right-hand edge slightly separated from the others—alone communicates with the vaporizing space. This is the starting and idling tube, or, nozzle. As the throttle is revolved, the spiral edge brings the other tubes into play, one at a time, until the whole number is engaged. When the throttle is revolved to the full opening, its central portion, as shown in the left-hand figure, is seen to be somewhat restricted at the center and flared at the ends to produce a slightly modified Venturi shape. The passage above the throttle leading to the inlet manifold, and the shape of the passage below it through which the air enters, both contribute to this effect.

The air enters from the right, Fig. 98, and the shape of this passage, to match the general shape of the carburetor, is low but wide. This has led to the development of a variable method of furnishing the air; for a division in the end of the passage allows of having all cold air, half cold and half hot, or all hot, as desired. For the heavy fuel conditions under which the device was developed, the all-hot air arrangement was used. Except in the hot summer months this would be most desirable, but there are conditions under which the semi-hot air arrangement would be best.

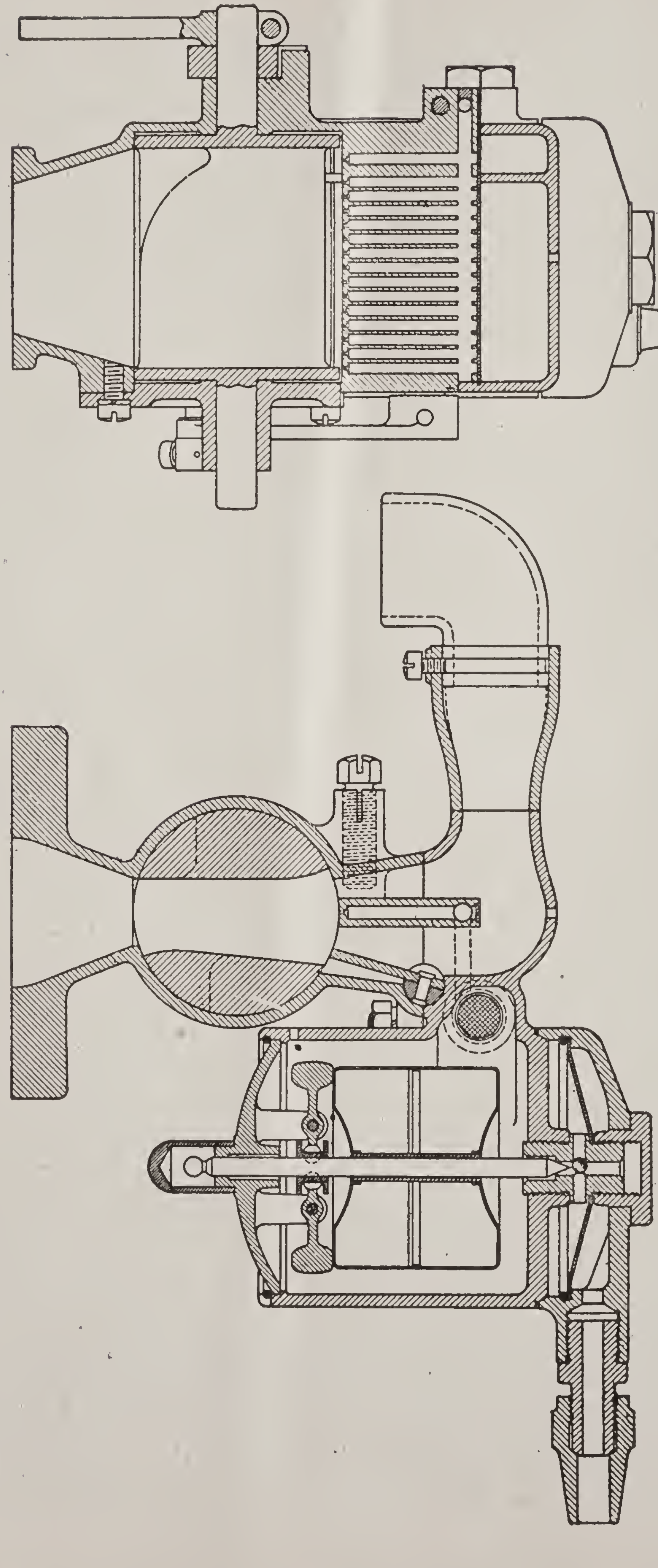


Fig. 98. Section through the Master Carburetor, Which Is a Multiple-Nozzle Form and Handles Heavy Fuels Well
Courtesy of Master Carburetor Company, Detroit, Michigan

Adjustment. While it is said not to have any adjustment, there is a variation which corresponds to the adjustment in many carburetors. This is the air damper, which is a long, rigid, flat plate extending across the incoming air passage parallel to the distributor and is connected by means of a Bowden wire mechanism to an operating lever on the steering post in the position where the usual carburetor adjustment is located. When this is moved, the air damper is swung over toward, or away from, the distributor. This movement restricts or increases the air passage at the jets. When the damper is moved so as to restrict the passage of air, its velocity is increased, and the greater suction carries up more fuel from the jets, and thereby produces a richer mixture. On the other hand, when the damper is moved to enlarge the area, there is less suction; consequently less fuel is drawn up, and the mixture is leaner. In the sense that the operator can change nozzles or modify the maximum or minimum amount of air or fuel entering the carburetor, this device has no adjustments. The nozzles cannot be changed in any way, and the amount of air can be varied only in a wholesale way, i.e., by changing from lean to rich through the whole range between these two. This device has been used four years as regular equipment on Moreland trucks which are built to use distillate selling at 6 cents a gallon, in barrel lots. This fuel has a specific gravity of 51 at 60° F.

When made for Ford cars, this device has only 11 nozzles. On the larger sizes from 14 to 19 are employed. The use of this device, with its vertical opening, necessitates a special inlet manifold to replace that on the Ford which provides for a horizontal carburetor outlet.

Miller Racing Carburetor. A carburetting device very similar to the Master is that shown in Fig. 99, this being the Miller carburetor. Proof of its efficiency is shown by its very wide use on the highest powered engines, such as the King-Bugatti 16-cylinder aeronautic engine, the Duesenberg line of racing and airplane engines, and on the majority of recent racing cars.

As will be noted in the figure (this showing the carburetor as used on the King-Bugatti 400-horsepower engine), a number of screwed-in jets are used, in the case of this particular engine, the number being seven, while the number of carburetors used was four, one for each four cylinders. In ordinary racing practice one or two of the seven-jet carburetors are used.

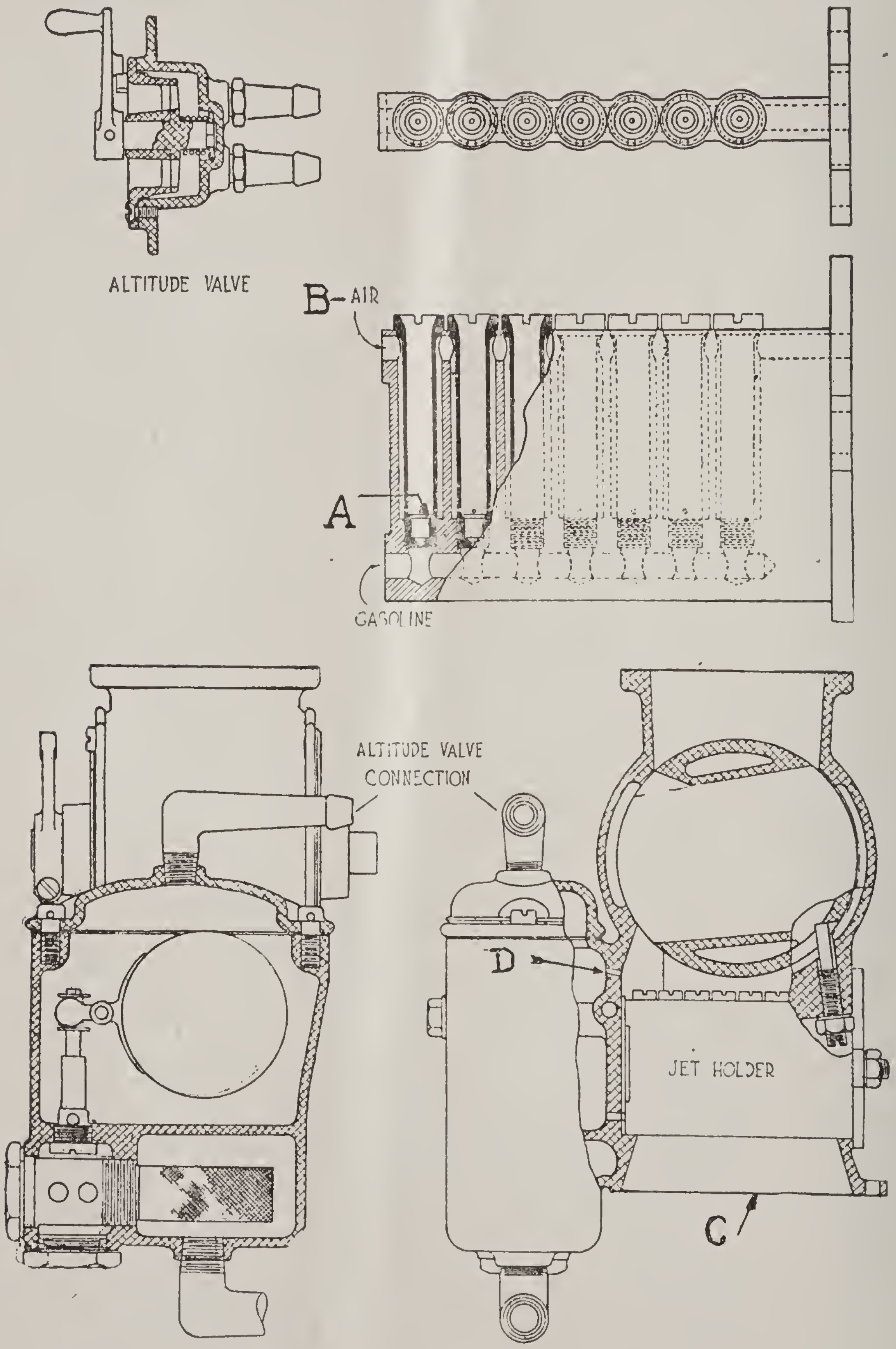


Fig. 99. Miller Multi-Jet Carburetor and Altitude Valve Details
Courtesy H. A. Miller Manufacturing Company, Los Angeles, California

As the general view and detail indicate, gasoline is drawn into each one of the jets through the small hole in the bottom of the threaded end, mixing with a certain amount of air sucked in through the four small holes at *A* drilled in the barrel of the jet just above the threaded portion. This air is taken from the outside through the upper $\frac{3}{16}$-inch hole *B* in the jet holder, and passes down around the outside of the jet to the four small holes mentioned. The major portion of the air enters the carburetor through the lower end *C* of the Venturi, which is 3 inches in diameter, passes up around the jet bar holder, combining above this with the rich mixture from the seven jets to form the proper mixture for combustion.

This particular instrument being for airplane use, an altitude adjustment is necessary, and the details of this are shown in the illustration. It operates by turning the lever, and has two openings in its seat which when open register with similar holes in the cover giving the free passages to the atmosphere. The float chamber is in direct connection with the Venturi through the drilled hole *D* $\frac{5}{64}$ inch in diameter, this being well above the fuel level. When the altitude control valve is opened, by this means, the vacuum in the float chamber is decreased, thus increasing the flow of fuel through the jets.

Like the Master, this has no adjustment, changes in performance being produced by replacing the jets with different ones.

Webber Automatic Carburetor. The Webber carburetor has been produced to meet the need for a very finely and carefully made instrument. It is an instrument of precision and is priced accordingly. Two models are made, namely, Model "C," which has a vertical outlet and water jacket; and Model "E," which has a horizontal outlet and no water jacket and is therefore smaller and more compact. With these exceptions, the two are very similar in construction, as well as in adjustment. For this reason only the Model "C" will be shown. This will be seen in Fig. 100, which shows a longitudinal section along the center line of the two chambers. It will be noted that this device has a concentric float *37* in which the spray nozzle *35* is located. The needle point *32* is controlled through the needle-point lever *13* which works down onto it from above. The nozzle is placed in the center of the modified Venturi chamber *7*, the top outlet of which consists of a series of 10 tapered holes. As the fuel mixed with the hot air entering through the air horn *9* reaches the vaporizing chamber, the auxiliary air enters from the side. Because of the shape of the cylindrical vaporizing chamber

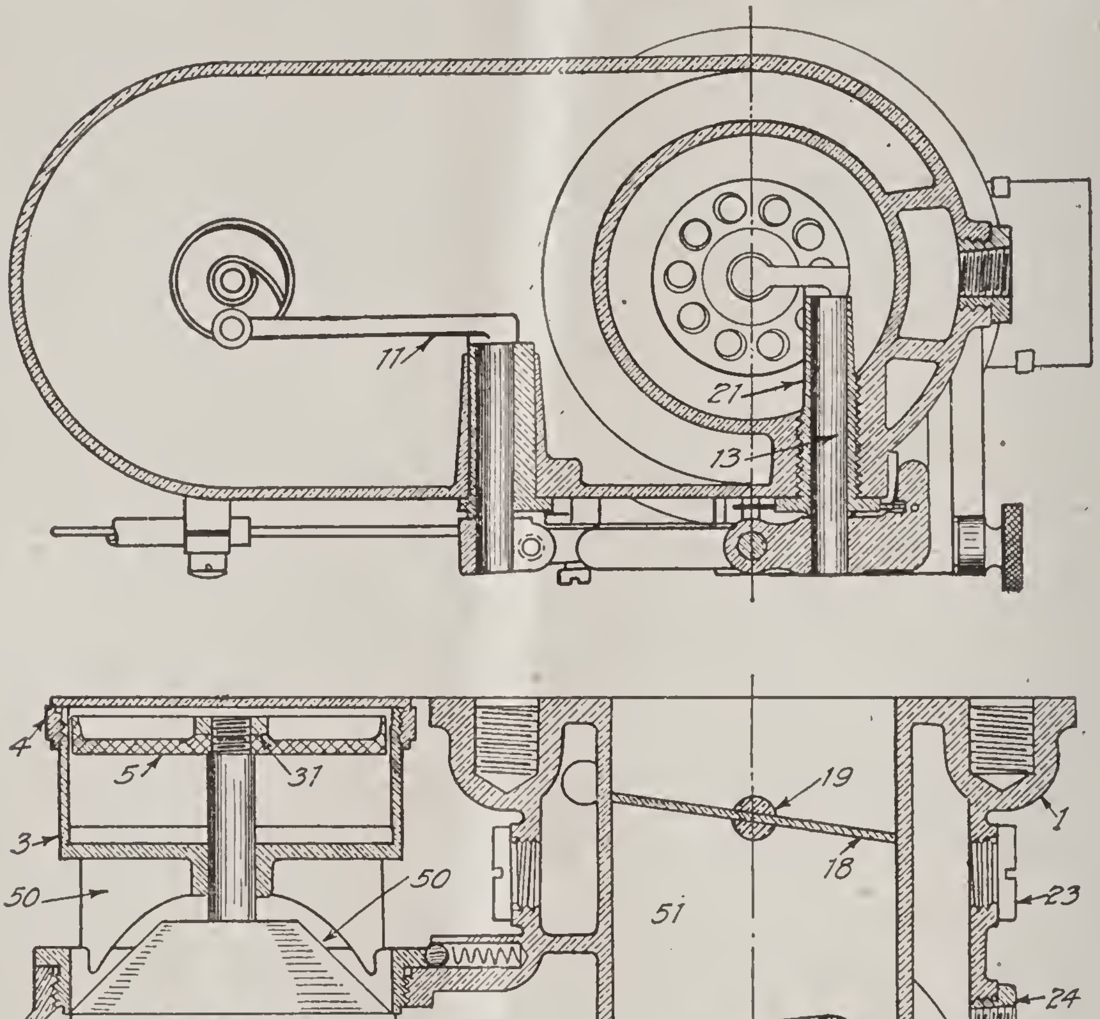


Fig. 100. Section through Webber Automatic Carburetor
Courtesy of Webber Manufacturing Company, Boston, Massachusetts

51 and the distance which this chamber extends downward, the auxiliary air is forced to turn at right angles and also to pass through a restricted area, thus giving it an increased velocity where it picks up the partly vaporized fuel. In this upper cylindrical vaporizing chamber *51* the throttle valve *18* of the simple butterfly type is located.

The auxiliary air enters through the holes *50* below the dashpot chamber *3* in which the piston *5* is located. This is attached to the upper end of the auxiliary air-valve stem, its lower part having a conical extended shape so as to spread out the air. The dashpot prevents fluttering while the downward movement of the air valve is resisted by the spring *34*. The tension of the spring is adjustable

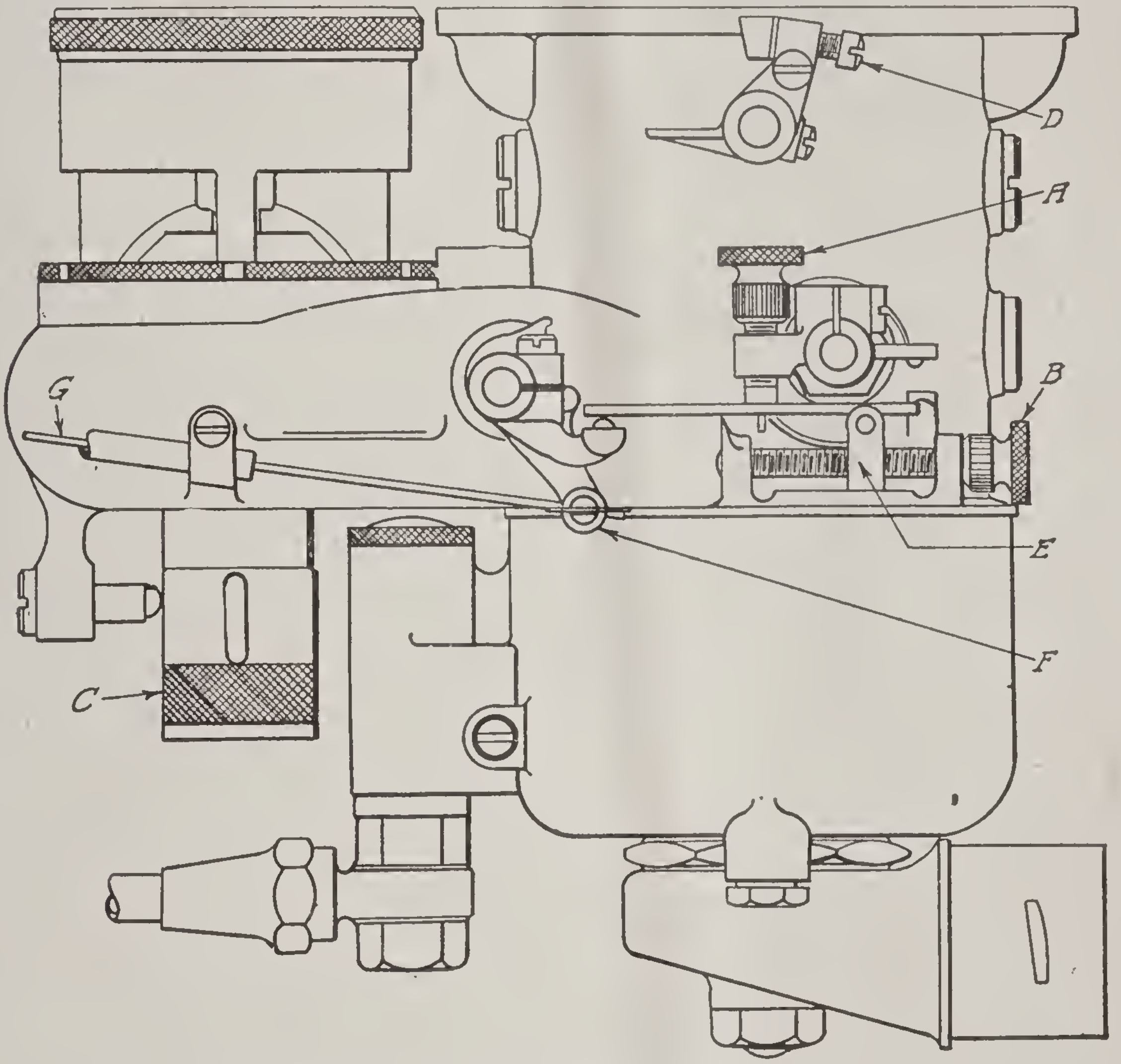


Fig. 101. External View of Webber Carburetor, Showing Adjustments

by means of the milled thimble *28* and the locking plunger *30*. The air-valve lever *11* is interconnected with the needle-valve lever *13*, so that any movement which increases the air opening automatically increases the fuel flow also, and *vice versa*.

Adjusting the Webber. There are two adjustments, aside from the setting of the air valve and the determination of the proper needle valve and its correctly proportioned spring. These are for low speed, or idling, and for high speed, or maximum power. Assuming that the carburetor has been installed correctly and the fuel turned on, the makers recommend turning the air-valve adjusting-spring thimble *C*, Fig. 101, up or down until the air valve upon being pressed down and released returns lightly but positively to its seat. Next turn the low-speed adjusting screw *A* down (right handed, or clockwise) as far as it will go without resistance, then turn it up, or back, about three-fourths turn. Turn the high-speed adjusting screw *B* to the right or left until the fulcrum block *E* is approximately in the center of its travel. Be sure that when the lever of the steering-post control (handle operating Bowden wire) is moved down to the lean position, the lever *F* on the carburetor is pressed forward firmly against its stop.

Low-Speed Adjustment. Move the lever of the steering control to the rich position, open the throttle about one-quarter, then start the motor. Now move the lever on the steering-column control down to the lean position and allow the motor to run idle until thoroughly warmed up. If it does not idle properly, turn the low-speed adjusting screw *A* up or down until it runs smoothly with the throttle closed against the stop screw *D*. The latter, after being adjusted properly, should be fastened by setting up the clamp screw provided for this purpose. This adjustment is for idling only.

High-Speed Adjustment. The high-speed adjustment is made by turning the screw *B* to the left or right. This moves the fulcrum block *E* in or out; moving it in gives less gasoline at high speed, and moving it out gives more gasoline at high speed. This adjustment can be made with the motor standing and continued until what seems to be the best position is reached; but the final high-speed adjustment should be made on a long hill. On this, start up at the bottom at about 20 miles per hour, open the throttle wide, and note the speed at the top. Now go down the hill. After moving the fulcrum block *E* out about $\frac{1}{16}$ inch, try the hill a second time, starting from the bottom at the same speed as before and noting particularly the speed which results at the top. If this shows a gain, move the fulcrum block out another $\frac{1}{16}$ inch and try again. If it shows a loss, move the fulcrum block in and then try the hill. Continue until the maximum speed at the top of the hill is obtained, then lock the adjustment. This means but a few trips up and down the hill and results in a setting which is permanent and gives maximum power at all times. This adjustment is for maximum power only and has no effect upon the idling adjustment made previously. Be careful also not to pass the point of maximum power; as this point means maximum speed, flexibility, and acceleration.

Starting Adjustment. The makers claim that it is unnecessary when the proper adjustments have been made to wait for the motor to warm up before starting away; simply move the steering-column control to the rich position, start the motor, and drive off, then, as the motor warms up, move this control lever down toward the lean position, running normally with this as far down toward lean as it will go.

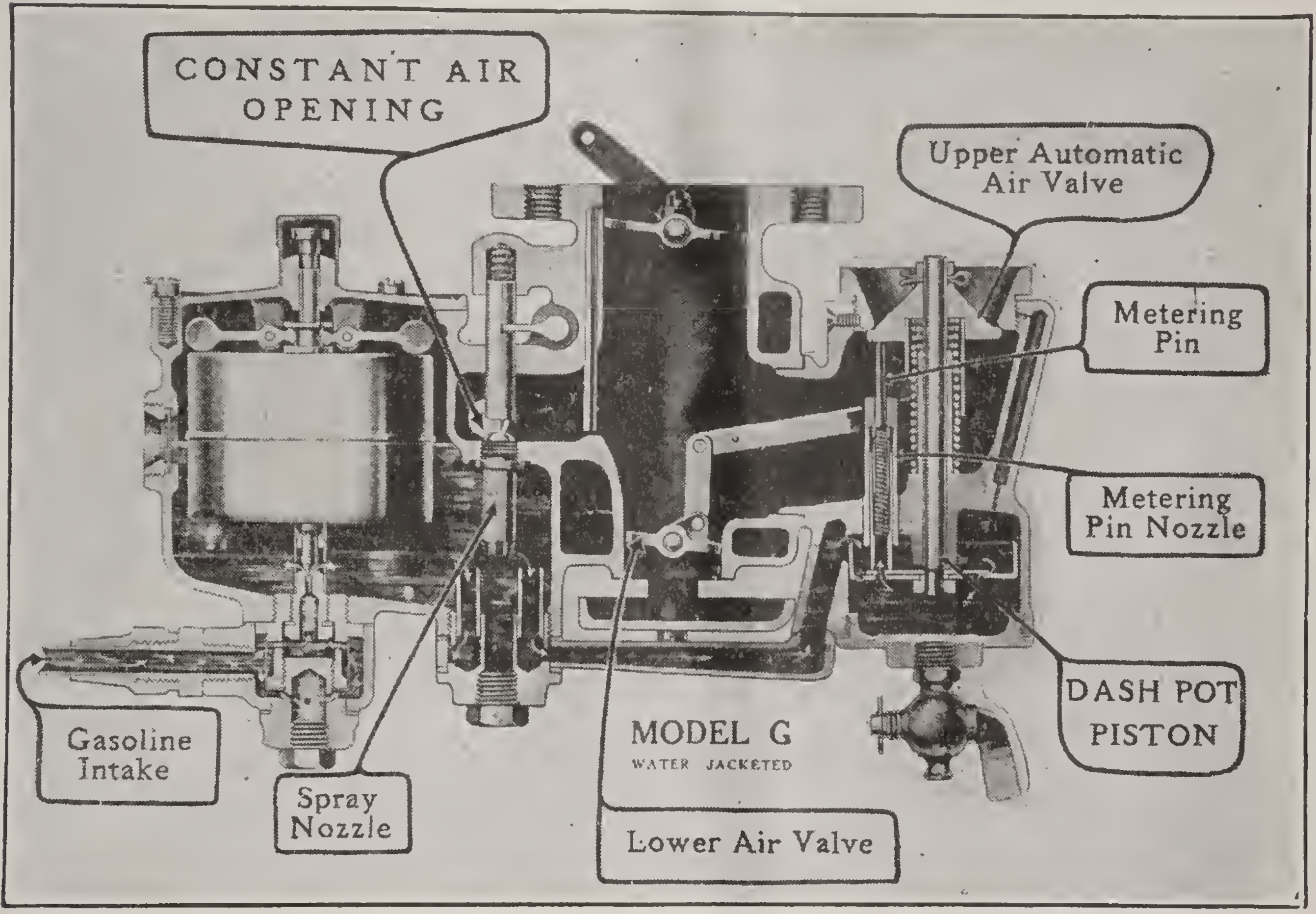


Fig. 102. Section of Rayfield Carburetor, Model "G"
Courtesy of Findeisen and Kropf Manufacturing Company, Chicago

Except that some of these adjusting screws are located differently, the adjustment of the Model "E" is the same as that of Model "C", as is also that of the Model "E H" a modification of the "E" adapted particularly to the Hupmobile.

Rayfield Carburetor. The Rayfield carburetor, Model "G", as shown in Fig. 102, is of the double-needle type, with three air-inlet openings and an eccentric float chamber. The latter is shown at the left, with fuel entering from below through a strainer. Communicating directly with this float chamber is the passage in which the low-speed nozzle (marked spray nozzle) is situated; this consists of a hollow member with the actual needle point coming down vertically from outside and above, similar to *C*, Fig. 82. Communicating with the float chamber is a passage, or well, through which fuel flows across to the bottom of the high-speed well. In this passage is located a hollow metering-pin nozzle; and in the upper part of it is the metering pin. The upper end, through which the fuel flows, is located in one end of the elongated vaporizing chamber, while the upper automatic air valve has access to the top of it and furnishes the air supply.

At the other end of the vaporizing chamber the idling needle is located, and directly beyond it is the constant air opening, a simple round hole communicating with the atmosphere. This end is short and close to the central portion of the chamber, which is approximately cylindrical. The lower air valve is at the bottom, while the vertical connection to the inlet manifold and the butterfly throttle are at the top. The lower air valve and the upper automatic air valve are linked together so as to operate simultaneously. The movement of the upper automatic air valve downward actuates the metering pin, moving it downward; this tends to allow fuel to flow out around the pin. At the same time, the stem of this valve is connected at the bottom with a piston working in the dashpot which is filled with fuel, so that any sudden tendency for the air valve to open is checked by this dashpot. At the same time, this piston communicates with the hollow metering-pin nozzle, so that the downward movement of the piston forces an extra supply of fuel into the nozzle and enriches the mixture. Thus, the opening of the throttle automatically produces a rich mixture for starting, as the slow movement of the air valve in opening against the drag of the dashpot causes a relatively stronger suction on the nozzles. This arrangement eliminates the necessity for an air-valve adjustment, that is, an adjustment which owner or repair man is supposed to use. As a matter of fact the carburetor is made with an adjusting ring, which, after setting at the factory, is locked by means of a set screw and is not supposed to be touched.

Adjustments. Referring to Fig. 103, there are but two simple adjustments on the Rayfield; both are made by means of external milled head screws. Before making any adjustments, be sure there are no obstructions in the gasoline line, that all manifold connections are tight and free from air leaks, that valves and ignition are correctly timed, and that there is good compression and a hot spark in all cylinders. These carburetors are generally fitted with dash control.

Always adjust the carburetor with this dash control down. The low-speed adjustment should be made first. To make this, close the throttle and let the dash control down, then close the nozzle needle by turning the low-speed adjustment, Fig. 103, to the left until the block *U* leaves contact with the cam *M* slightly. Then turn to the right about three full turns. Start the motor and allow it to run until warmed up, then push the dash control all the way down, retard the spark, close the throttle until the motor runs slowly without stopping. Now make the final adjustment by turning the low-speed screw to the left until the motor slows down. Next, turn to the right, one notch at a time, until the motor idles smoothly. If the motor does not throttle low enough, turn the stop-arm screw on the main throttle-valve shaft to the left until the motor does run at the minimum speed desired.

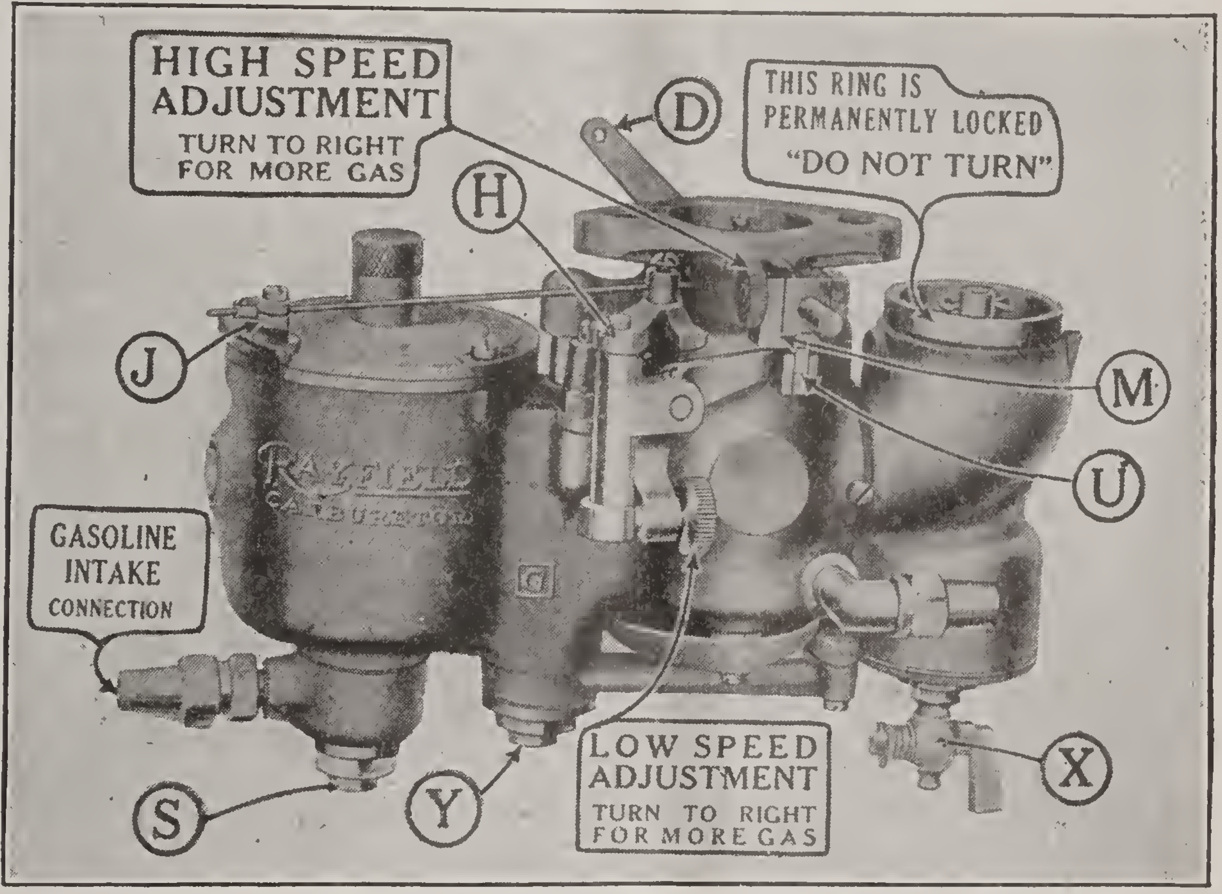

HIGH SPEED ADJUSTMENT
TURN TO RIGHT FOR MORE GAS
D
THIS RING IS PERMANENTLY LOCKED "DO NOT TURN"
H
J
M
U
RAYFIELD CARBURETOR
G
GASOLINE INTAKE CONNECTION
LOW SPEED ADJUSTMENT
TURN TO RIGHT FOR MORE GAS
X
S
Y

Fig. 103. External View of Rayfield Carburetor, Model "G", Showing Adjustments

High-Speed Adjustment. Advance the spark about one-quarter with the motor running, then open the throttle quickly. Should the motor back-fire, it indicates a lean mixture. Correct this by turning the high-speed adjusting screw, Fig. 103, to the right, about one notch at a time, until the throttle can be opened quickly without back-firing. If loading, or choking, is experienced when the motor is running under heavy load with the throttle wide open, it indicates too rich a mixture. This can be overcome by turning the high-speed adjustment to the left. Adjustments made for high speed will not affect low speed. Low-speed adjustments must not be used to get a correct mixture at high speed. Both adjustments are positively locked.

Changing Nozzles. "Never, under any circumstances, change nozzles in the Models "G" and "L" carburetor," say the manufacturers. Neither should the float level be changed, as they say this is correctly set at the factory and should not be touched. For use with a pressure system, two pounds pressure is advised. The plugs *S*, *Y*, and *X* are for cleaning and draining purposes. In the bottom of the float chamber there is a strainer trap, which can be cleaned by shutting off the gasoline supply and removing the nut *S*. The dashpot is drained by opening the drain cock *X;* it is advisable to do this occasionally to remove any sediment that may have accumulated there. The float chamber should also be drained occasionally by removing the plug *Y*. When this is replaced, it should be tightened very carefully; and when the strainer trap is removed and cleaned, care should be taken in replacing it to put the gaskets back in place as well as to tighten the nut adequately.

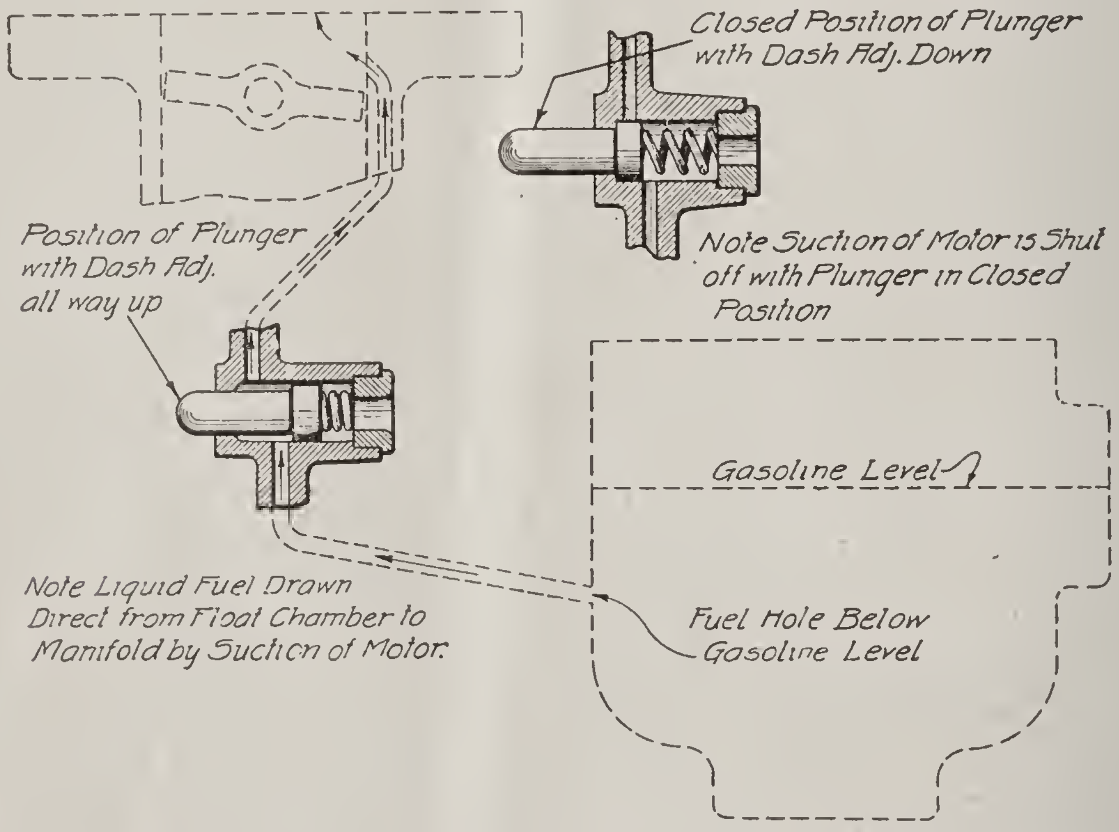

Closed Position of Plunger with Dash Adj. Down
Note Suction of Motor is Shut off with Plunger in Closed Position
Position of Plunger with Dash Adj. all way up
Gasoline Level
Note Liquid Fuel Drawn Direct from Float Chamber to Manifold by Suction of Motor.
Fuel Hole Below Gasoline Level

Fig. 104. Sketch of Starting Primer Attached to Model "N" Rayfield Carburetor

The Model "L" is the same as Model "G" without the water jacket. It is adjusted in the same manner, and all that has been said above on the subject of adjusting the "G" applies with equal force to the "L".

Adjusting Model "M". The Rayfield firm makes another model, known as Model "M", which is similar to the Model "L", except that it has a side, or horizontal, outlet. It has the same two adjustments, made in the same way, but the shape of the carburetor locates these in a different place. The low-speed adjusting screw is on the extreme top of the carburetor, and the high-speed adjusting screw is also on the top, but it is made accessible by removing the hot-air elbow from the main air valve. This model is fitted with a starting primer incorporated in the device itself and operated through the medium of a dash lever. In the sketch, Fig. 104, which is self-explanatory, the construction and operation of this are shown. When pressure feed is used, not more than one pound is recommended for Model "M". When the starting primer is to be attached, the following method should be used: Locate the position on the dash desired for the push button and drill a $\frac{5}{8}$-inch hole at the proper angle. Attach the adjustment and run the tubing to the bracket on the carburetor, avoiding sharp bends. Cut off the tubing so it will extend beyond the bracket not more than $\frac{1}{4}$ inch. Remove the temporary wire from the carburetor, insert the tubing and secure permanently by tightening the clamp screw. Run the dash adjustment wire through the hole in the binding post on the eccentric lever. Then, with the push button down, place the eccentric arm in position so that the line on the eccentric just comes in contact with the adjusting screw. Tighten the screw in the binding post, cut off the surplus wire, and, without changing the position of the push button, make the carburetor adjustment, as previously described.

Ball and Ball Carburetor. The Ball and Ball device has been developed by Frank H. and Frederick O. Ball and is named after them, but it is manufactured and sold by the Penberthy Injector Company. In all its forms, as used on a number of different cars, whether single or double, horizontal or vertical, it is a two-stage instrument. These two stages are called the primary and the secondary. As shown in Fig. 105, the primary stage corresponds to the usual simple air-valve carburetor. This consists of nozzle, or jet, *3*, located in the fixed air passage, or Venturi, *2*. In the passage above this, it receives its air for complete vaporization from the valve *4*. Some air is, of course, admitted around the nozzle *3* below the Venturi *2*, otherwise the fuel would not be drawn up. This nozzle receives its fuel from the float chamber *14*, which is supplied through a strainer in the usual manner from the gasoline pipe *13*. The connection from the float chamber to the jet extends first to the well *16*, thence across the horizontal passage *17*, from which the nozzle *3* draws its supply.

Now, to this simple carburetor add another which consists of the nozzle *6* and of the air supply *5*, which is normally closed by the butterfly throttle *7*; this latter, when closed by a spring, covers the top of the jet *6* so that it cannot function. It is obvious that the primary stage is constructed for low speed, idling, and for the lower range of driving, and is very economical. As this lower range covers perhaps 85 to 90 per cent of ordinary driving, this would be a desirable feature.

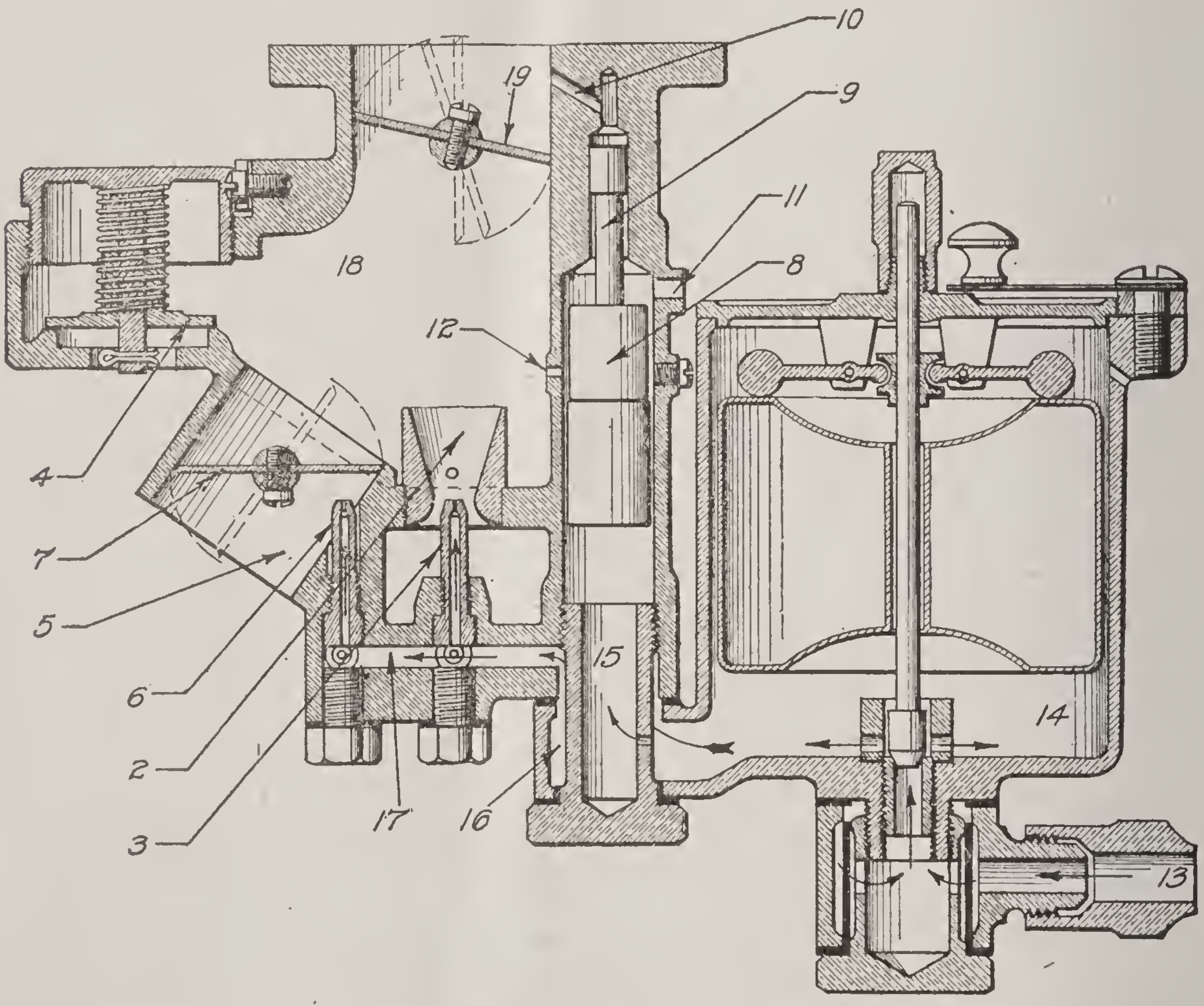


Fig. 105. Section through Ball and Ball Two-Stage Carburetor
Courtesy of Penberthy Injector Company, Detroit, Michigan

As the drawing shows, the opening of the second throttle valve *7* allows additional air to enter and, at the same time, uncovers the second jet *6*, so that this starts to function by drawing its gasoline from the same horizontal passage *17* as does the primary jet. If this throttle be connected up to the other throttle in such a way that, when approaching the maximum opening of the main throttle, the secondary throttle begins to open, we have, in effect, two carburetors, one working over the lower range, which gives good idling and splendid economy, and another high-speed and high-power device adding its total effect to that of the primary. The two contradictory and opposed qualities of highest power and highest economy are thus produced by what is, in effect, a double carburetor. This, with variations for various sizes and types of cars, constitutes the Ball and Ball device, shown in section in Fig. 105.

Pick-Up Device. This carburetor has a pick-up device which produces remarkable acceleration. This consists of the plunger *8* having a smaller sized upper end *9*. It is loosely fitted in the chamber *15*, the bottom of which communicates with the float chamber, and is thus kept full of gasoline. At the top, a small hole *10* communicates with the manifold above the throttle, while *11* is an opening to the atmosphere, and *12* is an opening to the mixing chamber. When the throttle is nearly closed, the vacuum in the manifold raises the plunger, and the space below it fills with gasoline. In this position it is ready to act. When the throttle is opened suddenly, the vacuum is broken, and the plunger drops of its own weight, forcing the gasoline up where it is swept into the mixing chamber by the air entering through the passages *11* and *12*. This is repeated as often as the throttle is suddenly opened from a nearly closed position.

Adjustments. The primary stage must be adjusted as a whole to give the best idling and slow speeds; this consists of the adjustment of the air-valve spring, the arrangement of the hot-air passage leading to it, or, if these prove insufficient, the changing of the primary nozzle. The last change is opposed by the makers.

Beyond this, the only adjustment possible lies in the hot-air choke valve which can be moved or altered from the dash to give more or less hot air. The partial closing of this valve makes starting easier and helps the running of the motor until it gets warmed up, but in normal running its manipulation has little effect. In going farther than this, the only possibility lies in altering the design by varying the connection between the two throttles, so the second stage cuts in sooner or later, but this might impair the usefulness of the instrument. The same is true if the secondary nozzle is changed. The device, then, is really lacking in adjustments in the ordinary sense, except for the initial setting of the primary-stage air valve.

Newcomb Carburetor. The Newcomb carburetor is made by the Holtzer-Cabot Electric Company and is a constant vacuum type having a single nozzle and an eccentric float chamber. It is a high-grade instrument and is used only on the highest-priced cars. As shown in Fig. 106, the hot-water-jacketed vaporizing chamber will be noted at the left. In the center of it is the hollow plunger *69*, which works up and down in the plunger chamber *68*. The top portion of the plunger has the needle holder *73* held in place by the lock nut *74*. The hollow plunger *69* surrounds a tube at the top of which the fuel nozzle *72* is located. The fuel controlling needle *71* is fixed in the needle holder *73* and projects through this nozzle down into the central fuel well. This is connected by a horizontal passage at the bottom to the lower part of the float chamber, seen at the right,

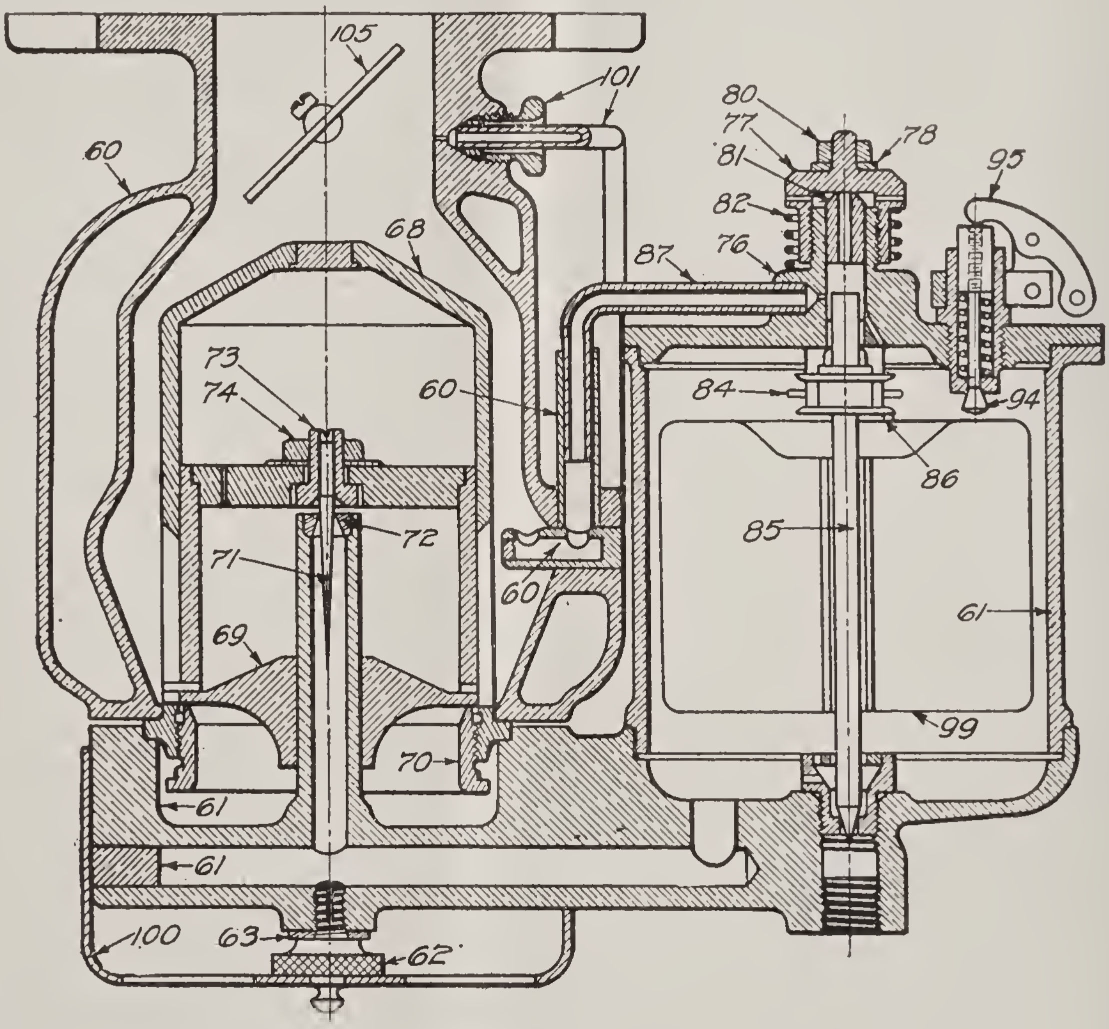


Fig. 106. Section through Newcomb Carburetor
Courtesy of Holtzer-Cabot Electric Company, Boston, Massachusetts

which is of normal, or usual, construction, except for the regulating cap *77* on the top of the central opening above the float needle *85*.

Around the bottom edge of the plunger *69* a large number of holes of small size are drilled, and these are arranged to register with an equal number of relatively narrow air slots cut in the bottom of the plunger chamber walls. These distribute the fuel after it has passed up the central well, issued from the nozzle, and been drawn within the plunger. The plunger when at rest is seated on the collar *70*, which is threaded into the bottom of the plunger chamber and is used as a means of adjustment, as will be explained later. This collar is so set as to raise the plunger slightly, thus opening the fuel nozzle without uncovering the air slots in the plunger chamber. In this way, the fuel port is given a lead with respect to the air ports, so that a rich mixture is delivered when the plunger is raised a little, as in starting or idling.

When air is drawn through the carburetor by the motor suction, the plunger lifts in proportion to the amount of air entering. This lifts the needle and, at the same time, releases the exact amount of fuel needed to charge the entering air correctly and thoroughly. The higher the plunger is lifted, the greater the air and fuel openings. The effective areas of these air and fuel ports are so proportioned as to be correct at all positions. The slots in the plunger chamber walls being small, the jets of air coming through them have a high velocity, so that the fuel is atomized as it issues at these points. Any unatomized or unvaporized fuel is thrown against the heated walls of the vaporizing chamber, which are made greatest in area in this region. This produces a dry gas and high fuel economy. The gas passes around the outside of the plunger chamber, through the main throttle valve, and thence goes into the inlet manifold.

Starting Device. The small pipe shown at *101* is a starting device and consists of a pipe connection from the lower part of the float chamber into the gas outlet passage above the throttle valve. When about to start, the throttle is thrown over to a position in which the opening of this pipe is included in the manifold above it. It is then susceptible to the partial vacuum existing there, and pure fuel in a very fine spray is drawn directly into the manifold. Under normal running conditions, its operation is negligible.

The Dashpot. This device has a solid head to the plunger *69* and also to the plunger chamber *68* in which it works. Between the two there is a considerable space, and, as the plunger is a fairly close fit in the chamber, this acts as a dashpot and retards the speed of the plunger when the motor is accelerating, or when the throttle is opened suddenly. By retarding the speed of the plunger, a richer mixture is obtained at the precise time when it is needed, in fact, demanded, by the motor. And yet when the plunger rises and stops rising, the mixture again becomes normal. This arrangement, therefore, does not need an extra rich setting in order to obtain good acceleration, for the engine can run on a lean mixture with a rapid pick-up.

Mixture Indicating Pointer. The top of the float chamber carries a name plate *88* on which a graduated arc varying from *1* to *9* is etched; the *1* end being marked poor, and the *9* end rich, as shown in Fig. 107. On the top center of the float chamber is a regulating cap *77*, Fig. 106; attached to the top of it is the regulating pointer *78*, which traverses the arc shown and in this way indicates the quality of the mixture being formed with that setting. This pointer, shown as straight, but having two bends, from a horizontal to a vertical and back to a horizontal at the scale, has a small hole at one end to which a dashboard controlling lever can be attached, thus a quick and easy adjustment can be obtained. This pointer, which carries with it the regulating cap *77*, Fig. 106, adjusts the degree of vacuum above the gasoline in the float chamber and this holds back or partially restrains the flow of fuel to the nozzle. When turned to poor, the vacuum is increased, and the flow of fuel is reduced, giving a weaker, or leaner, mixture. When turned to rich, the vacuum is reduced so the fuel flow is increased and results in a richer mixture. This effect is felt throughout the range of throttle opening and thus throughout the speed range. It is used also to compensate for changes in temperature, altitude, and varying fuel densities. This vacuum arrangement replaces the usual change of area of the fuel opening in other carburetors.

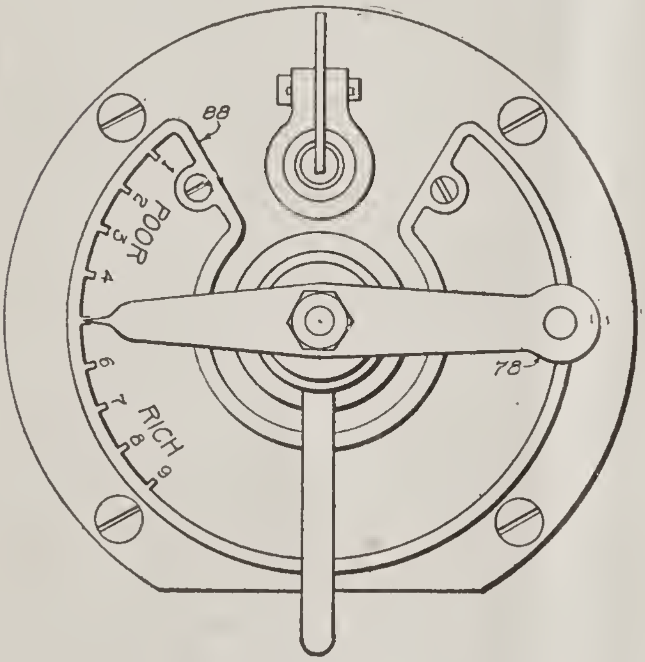


Fig. 107. Sketch of Regulating Pointer on Newcomb Carburetor

Adjustments. There are but two adjustments: the load-carrying adjustment controlled by the pointer *78* and cap *77* just described; and the idling adjustment controlled by the regulating collar *70*, mentioned previously, and shown in Fig. 106. Contrary to the usual method, the load-carrying adjustment is made first, and the low-speed, or idling, adjustment is made last. To make the load-carrying adjustment, set the throttle in the special starting position as described, turn the regulating pointer to the rich position on the dial, then screw the slow-speed ring, or regulating collar, *70* as far up as it will go. This is the rich position of the ring for starting only. Flood the carburetor by means of the tickler *94* until gasoline appears on top of the float chamber. Then start the motor and immediately move the throttle to a running position, otherwise the motor will stall.

With the motor running normally, move the regulating pointer *78* to about 5 on the dial; this gives an average setting, but different points should be tried and the poor-mixture, or lean-mixture, side should be favored always. To obtain the best setting, move the pointer half a point at a time, and try out the setting each time on the road. When the best setting has been found for some one condition of motor speed and load, the mixture will be found correct under all conditions except idling.

Idling and Low-Speed Adjustment. Now that the load-carrying adjustment has been made, the ring *70* which adjusts the mixture for idling should be unscrewed to weaken the mixture until the motor throttles evenly, without loading or popping when accelerated. Possibly the best combination of slow running and quick smooth acceleration may call for a slightly richer mixture than that on which the motor idles best and slowest. After this setting has been made, to see if the ring is screwed up too far and is giving a richer mixture than is necessary, move the regulating pointer *78* slowly from the No. 5 point toward poor. If the motor speeds up, the mixture is too rich, and the ring *70* should be unscrewed until the motor idles correctly with the pointer in the position found to be correct for the load-carrying mixture. After the correct idling position has been found, all variations for atmosphere, temperature, and fuel conditions should be made by changing the pointer only.

Newcomb Air-heated Model. In addition to Model "B" just shown and described, the Newcomb is made in an air-heated form shown in Fig. 108. This is known as Model "E," and differs from Model "B" mainly in the method of heating (air instead of water), the slow speed adjustment, and the arrangement of the high speed adjustment.

In place of the adjusting ring *70* which raises or lowers the plunger in Model "B," spray nozzle is raised or lowered by means of an adjusting thumb nut at the bottom of the carburetor and outside. This is seen at the bottom of Fig. 108, which shows also how this nozzle would be withdrawn from the metering needle or raised to it by such movement. The high speed adjustment is much the same in principle, but instead of the pointer on top of the float chamber a lever hung in a vertical plane works upon a pin "A" between the float chamber and body, this by its position governing the amount of vacuum above the fuel, and thus, its flow. The starting device is similar to the pipe *101*, Fig. 106, but the fuel is broken up by the knurled edge of a pulverizing ring in the throat above the throttle, the knurling doing the actual work of pulverization.

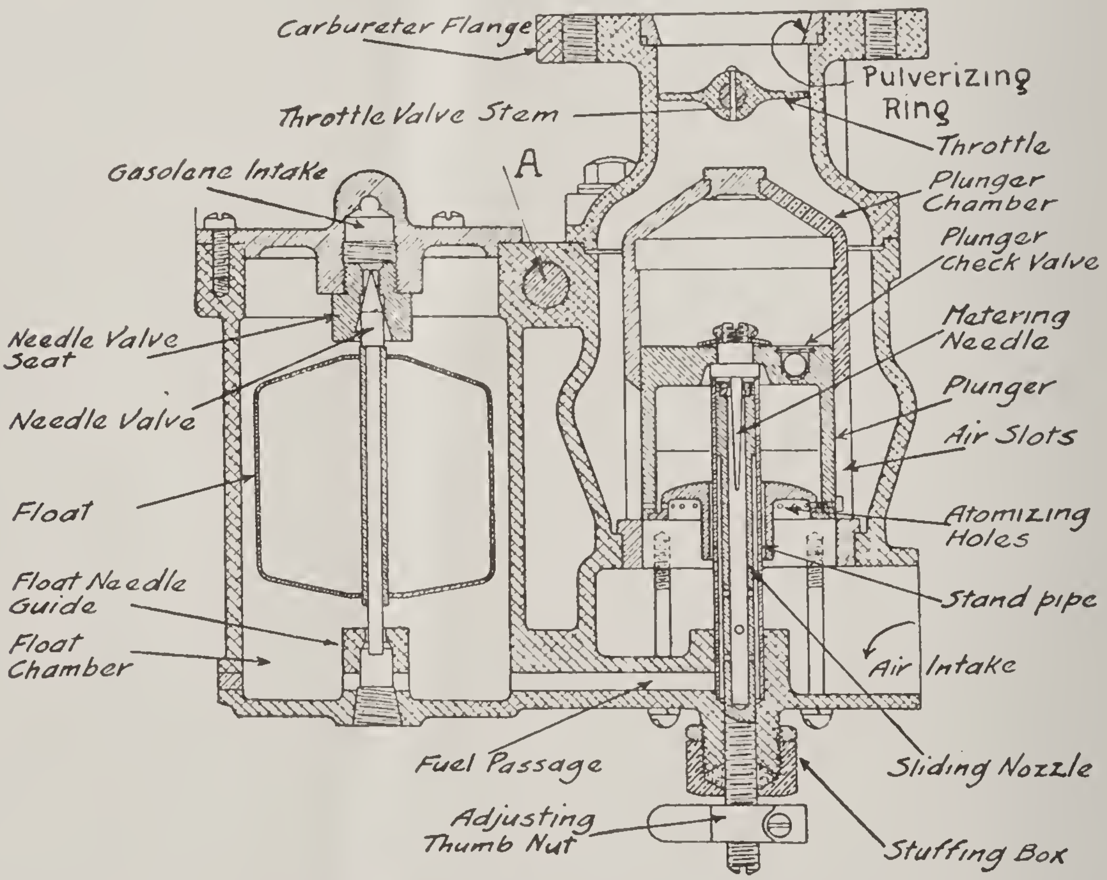


Fig. 108. Section through Newcomb Model "E" Air-Heated Type Carburetor
Courtesy Holtzer-Cabot Electric Company, Boston, Massachusetts

Marvel Carburetor. The Marvel carburetor, Model "E," shown in section in Fig. 109, is notable for using the exhaust gases directly for heating the vaporizing chamber, as well as for pre-heating the air used for vaporizing the fuel. The latter is common enough, but in the usual case where heating is thought necessary, hot water from the motor's water-circulating system is used. Another novelty in this design is the inclined hinged form of air valve set across the lower part of the vaporizing chamber. The float chamber *A* is eccentric to the central vaporizing chamber *B*, but is set very close to it, so the ends of the cylindrical float *C* have to be cut off for clearance.

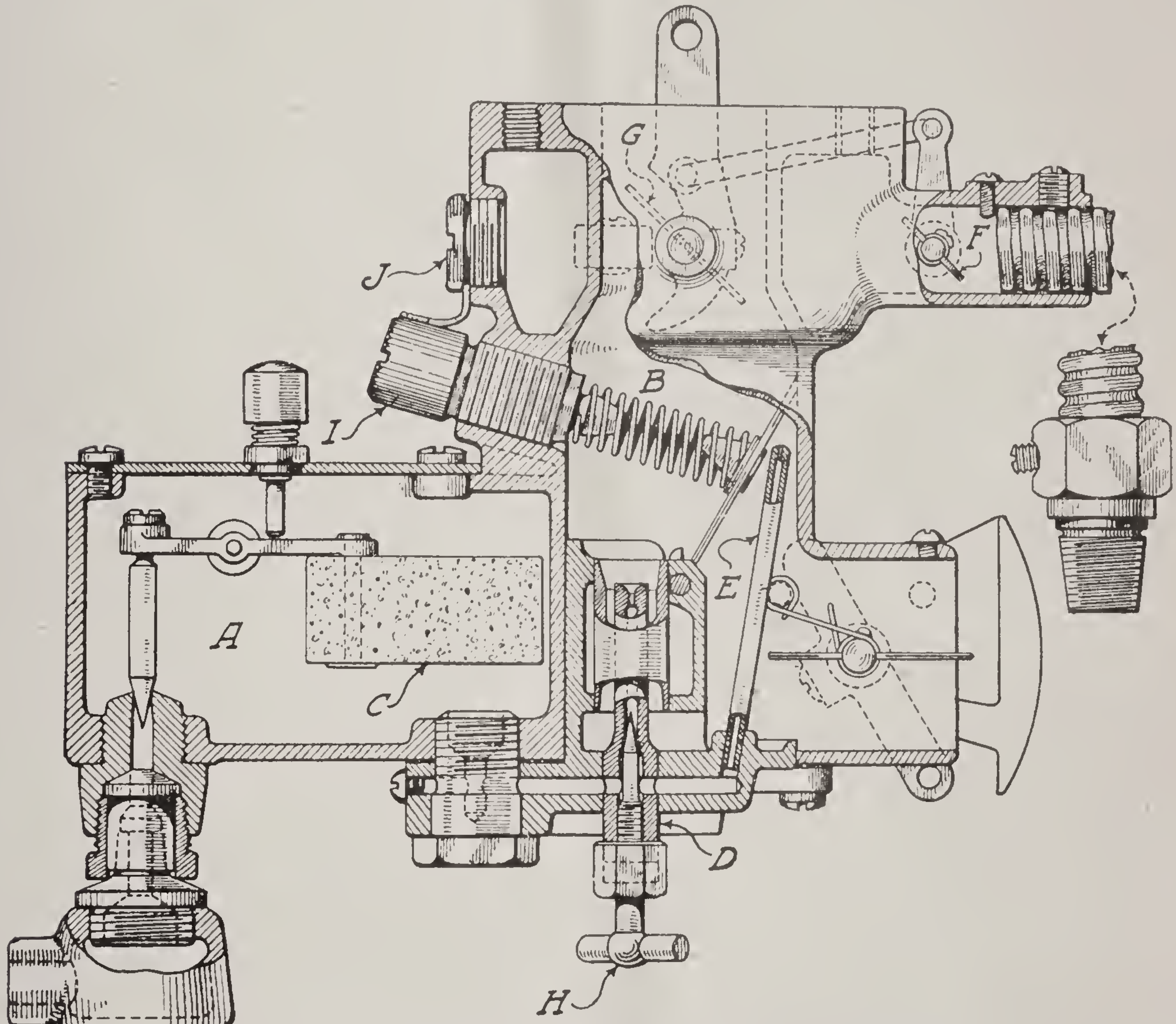


Fig. 109. Section through Marvel Carburetor, Model "E"
Courtesy of Marvel Carburetor Company, Flint, Michigan

Fuel enters from below. It enters the gasoline passage from above, as this is horizontal. The primary, or low-speed, nozzle *D*, which is adjustable, takes off from this about midway of its length, and the high-speed nozzle *E* from the end. The former operates within a Venturi tube which is supplied with air from below. Above this, the chamber broadens out through the zone in which the high-speed nozzle contributes, but above that it narrows down again before meeting the outlet, the last few inches having exhaust heat applied around it.

These exhaust gases pass downward through an external cylindrical passage and, after warming the Venturi and primary nozzle region, escape to the atmosphere. This gas is obtained by tapping into the exhaust manifold within a few inches of the last cylinder outlet (4 inches are recommended). As the motor demand rises beyond the ability of the primary nozzle, the inclined air valve is drawn toward the vertical position, and, as soon as it leaves the cylinder wall, the high-speed nozzle is uncovered and starts to contribute. The air is supplied from the same air inlet, but it rises more directly. A throttle is placed in the air inlet to facilitate starting; closing this cuts off the air, so that a richer mixture is supplied. There is a damper, or throttle, *F* in the exhaust gas-inlet passage. It is interconnected with the main throttle *G* in such a way that it is opened when the latter is closed and closed when the latter is opened. The idea is to furnish a great quantity of heat when the throttle is nearly closed, and to gradually diminish the supply as the throttle is opened and the motor warms up.

Adjustments. There are two adjustments: the gasoline adjustment *H*, so-called by the maker, and the air adjustment *I*. The gasoline adjustment operates the primary nozzle. These preliminary adjustments can be made on the instrument as received by closing the gasoline needle valve *H* by turning it gently to the right until seated, then opening it by turning to the left $\frac{3}{4}$ turn. The air-adjusting screw *I* should be turned until the end of the screw is about even with the edge of the spring ratchet *J* provided to hold it when set. After starting, close the throttle to produce a moderate speed. Then close the gasoline needle *H* a very little at a time until the motor runs smoothly. Allow the motor to get thoroughly warmed up, though, before making the final adjustment.

Next, adjust the air valve. Turn the adjusting screw *I* to the left to back it out and release the air spring about one-eighth of a turn at a time until the motor begins to slow down. This indicates that the screw is too loose, so turn back slowly, one-eighth of a turn at a time, until it runs smoothly again. Next, advance the spark two-thirds of its travel and open the throttle quickly. The motor should speed up promptly and quickly. If it hesitates or pops back a little more gasoline should be released at the needle valve *H* by turning it to the left a very little at a time. It may also be necessary to tighten the air screw *I* a little more. Now, wait for the motor to settle down to this new adjustment, then open the throttle again quickly. Continue this sudden throttle opening and subsequent adjustment until the point is reached where the motor will respond in a satisfactory manner to a sudden throttle opening. The highest economy is obtained by turning the air screw to the left and the gasoline needle *H* to the right, closing it as nearly as possible and still obtain the desired results.

Fuel Supply. When the carburetor is fed by gravity, the bottom of the bowl should be at least eight inches below the bottom of the gasoline tank. When it is fed by pressure, one pound is sufficient, and two pounds should never be exceeded.

The Marvel Carburetor Company also makes a Model "N", designed for Ford cars to which it can be attached without change of manifold, levers, or other fittings. It is built on the same general plan as the Model "E" previously illustrated and described.

Schebler Carburetors. The Schebler carburetor is one of the simplest complete carburetors made. In general, all Scheblers have a concentric float; a single needle valve, the position of which can be adjusted to suit varying needs; and an auxiliary air valve which is also adjustable. In all these models, too, there is a primary air orifice of unvarying section. In the later models, the needle valve, or metering pin, as it is more correctly called, is interconnected with the air valve so that operation of the latter varies the former. Many models are made and all are still in use, but space forbids description of more than four: the widely used "L"; its successor, the "R"; and the latest form, the "A," made with vertical outlet and horizontal air inlet, much like the Zenith "L," which it resembles.

Adjustment of Model "L." It will be noted in Model "L," shown in Fig. 110, that the needle valve sets at an angle in the mixing chamber. The upper expansion of this chamber forms the vaporizing chamber of long rectangular shape with rounded ends and has the auxiliary air valve located at the other end of it. The vaporized mixture passes upward, by the throttle, and into the manifold. To adjust this model, turn the screw *A* down to make sure the air valve seats firmly, then close the needle valve by turning the adjusting screw *B* to the right until it stops; but do not apply pressure. Then turn it to the left four or five complete turns and prime, or flush, the carburetor by means of the priming lever *C*, holding this up about five seconds. Open the throttle one-third and start the motor, then close the throttle slightly and retard the spark. Next, adjust the throttle-lever screw *F* and needle-valve adjusting screw *B* until the motor runs at the desired speed, smoothly and evenly on all cylinders. Then make the high-speed adjustment on the dials *D* and *E*. Turn the pointer on the dial *D* from *1* toward *3*, about half way. Advance the spark and open the throttle so the roller on the track running below the dials is in line with the first dial. If the motor back-fires, turn the indicator a little more toward *3*, or, if the mixture is too rich, turn the indicator back toward *1* until it runs properly. Now open the throttle wide and make the adjustment on dial *E* for the high speed in the manner just completed on *D* for intermediate. As lean a mixture as the motor will stand is advised.

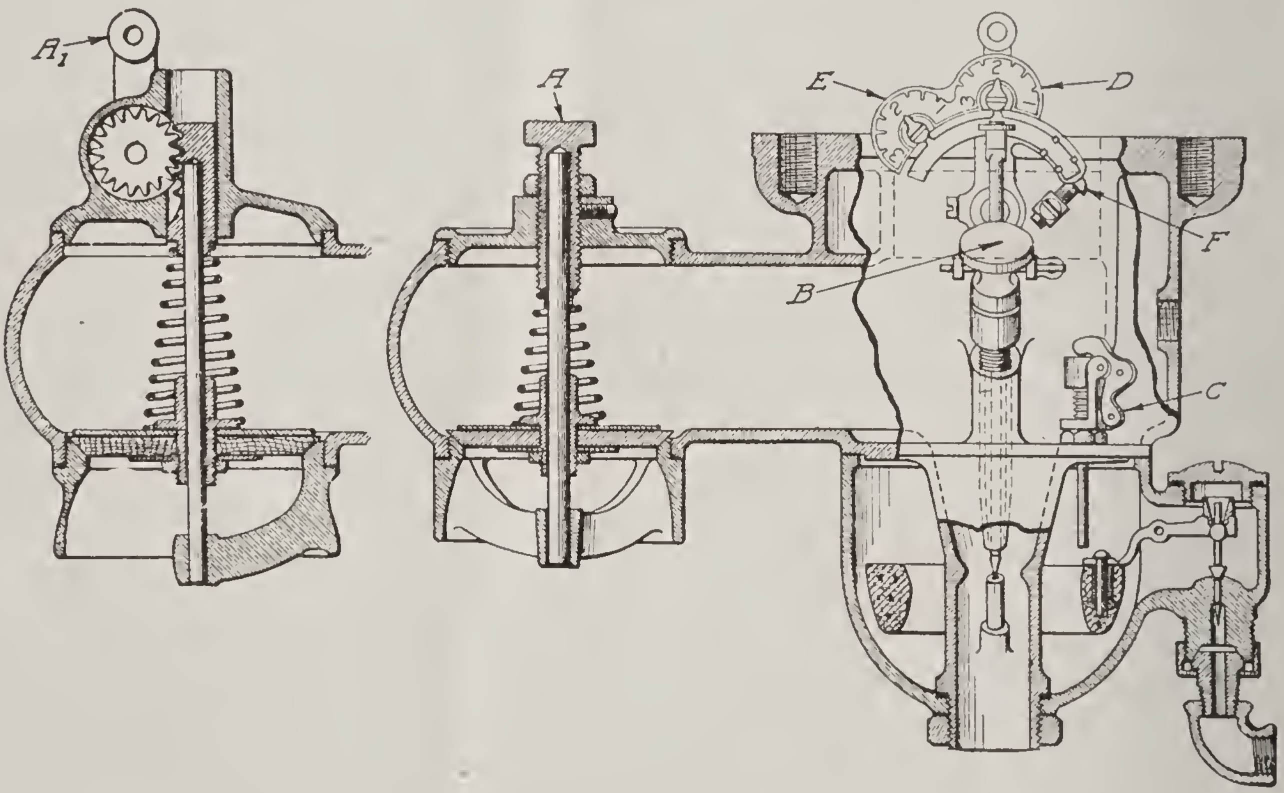


Fig. 110. Section through Schebler Carburetor, Model "L"
Courtesy of Wheeler and Schebler Company, Indianapolis, Indiana

This model is also made with a dash-control air valve, as shown separately at the left of Fig. 110. Otherwise the carburetor and adjustment are exactly the same, except that where the directions previously given above have read *A*, those dealing with the dashboard connection should read A_1. As will be noted, the movement of this lever rotates a small gear which engages with a rack formed in the air-valve stem, so that movement of the lever gives the same result as turning the screw *A*.

Adjustment of Model "R". Model "R", as Fig. 111. shows, is very similar, the most noticeable change being the vertical setting of the needle valve (here marked *E*). Its movement is adjusted by an internal lever connected to the air-valve cap *A*. The air inlet group has been raised to correspond with the longer Venturi, and its main opening is on top, with the adjusting screw *F* on the bottom. To adjust this model, see that lever *B* is attached to the steering-column control or dash control in such a way that the boss *D* is against the stop *C* when the lever on the steering column or dash registers lean, or air. This is the proper running position. To adjust, turn the air-valve cap *A* clockwise, or to the right, until it stops, then turn to the left, or counter-clockwise, one full turn. Open the throttle one-eighth to one-quarter, start the motor, let it warm up, then turn the air-valve cap *A* to left, or counter-clockwise, until the engine hits perfectly. Advance the spark three-quarters, and if the engine back-fires on quick acceleration, turn the adjusting screw *F* up until acceleration is satisfactory. This increases the tension on the air-valve spring. Turning the air-valve cap to the right, or clockwise, lifts the needle valve *E* out of the nozzle and enriches the mixture. Turning it counter-clockwise lowers it and makes the mixture lean. When the motor is cold or the car has been standing, move the steering-column or dash-control lever toward the gas, or rich, position. This lifts the needle *E* out of the nozzle and makes a rich mixture for starting. As the motor warms up, move the lever back toward the air, position to obtain the best running position.

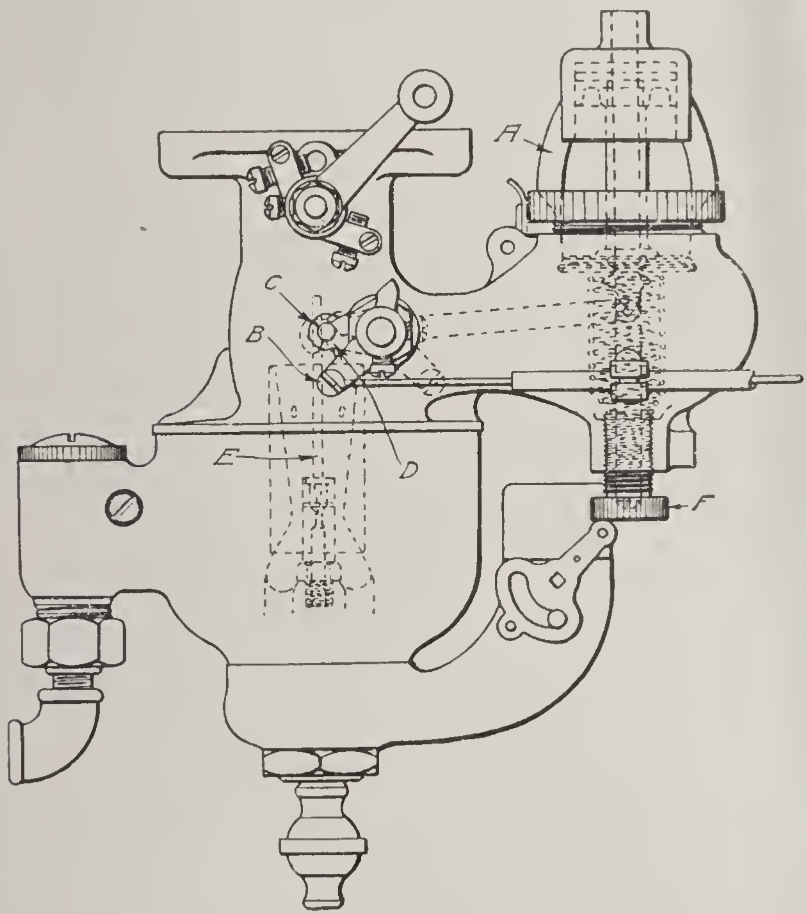


Fig. 111. Schebler Carburetor, Model "R"
Courtesy of Wheeler and Schebler, Indianapolis, Indiana

Adjustments of Model "A." The newest form, Model "A" is made in both the vertical and horizontal forms. Only the former will be illustrated here, this being shown in Fig. 112, which presents a vertical section. This is built around the principle of the "Pitot" tube, utilizing the differential head created by an up-stream and down-stream pitot tube to control the fuel delivery into the Venturi-shaped vaporizing chamber, to which the air has access from below. This arrangement gives a fuel flow exactly proportioned and controlled by the air. In the figure, *E* indicates the up-stream opening and *F* the down-stream nozzle of this arrangement, with air entering at the lower left through the passage there, which is controlled by the starting shutter *C*. The high speed adjustment is simple, and is made through the needle *B*. The low speed or idling device delivers fuel and air at the low edge of the throttle disc in its closed position, this being adjusted through needle *A* and the passages in the body of the carburetor, shown adjacent to *A*.

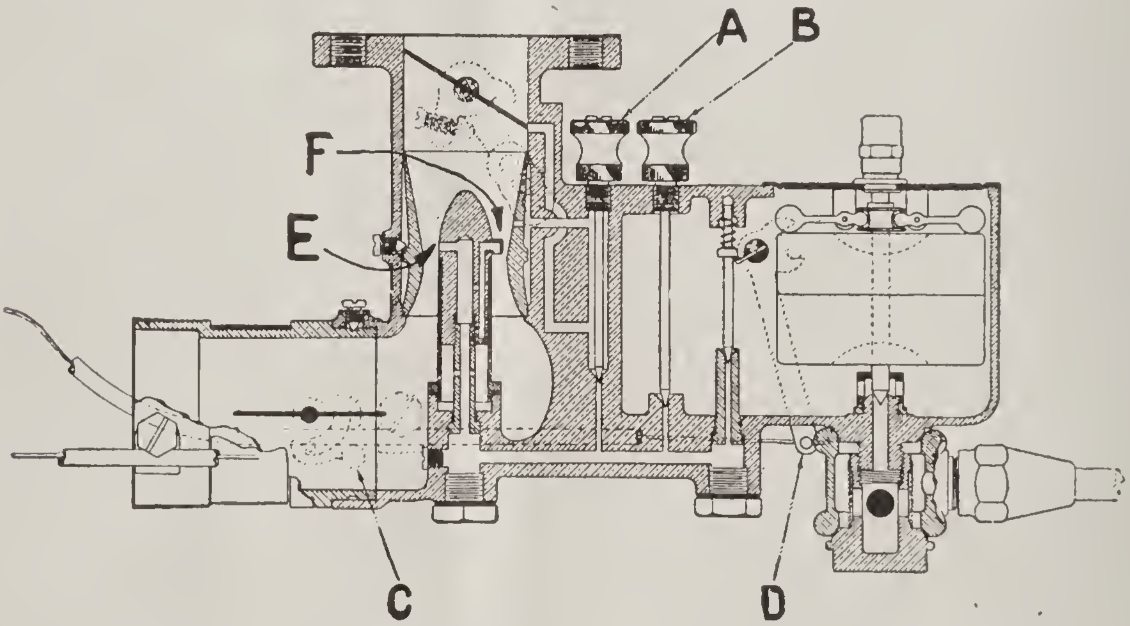


Fig. 112. Schebler Model "A" Carburetor, a Single Tube Device
Courtesy Wheeler and Schebler Company, Indianapolis, Indiana

Adjustment of Model "A." With the lever *D* set to give a rich mixture, and air choker *C* set to cut off all the air, both fuel nozzles *A* and *B* are opened 3 or 4 complete turns from the closed or seated position. Open throttle, start motor and let it warm up. Then with warming-up lever *D* fully retarded adjust *A* to correct mixture for idling. Open throttle $\frac{1}{4}$ and adjust high speed mixture with needle *B*.

Stewart Carburetor. The predominating feature of the Stewart Model "25" is the automatic metering valve by which the air admitted measures the gasoline used. This valve, which is the only moving part, is drawn upward by the suction of the motor and comes back down onto its seat through its own weight when the suction is lessened. In Fig. 113, the complete carburetor with the throttle open is shown at the right, and the vaporizing chamber only and with throttle closed is shown at the left; the float chamber is the same in both cases. Gasoline flows in through the strainer to the float chamber, thence to the dashpot, filling this and continuing to rise to a point about on a line with the top of the tapered metering pin, which corresponds to the usual needle valve.

With the engine at rest, as shown by the left-hand figure, the upper end of the metering valve, which has a conical lower surface, rests upon the valve seat, thus closing the main air passage. Its lower end extends down into the gasoline in the dashpot. Through its center is an opening, known as the aspirating tube, into the lower end of which extends (from below) the tapered metering pin. As soon as the motor starts, or is turned over, so that a partial vacuum is created in the mixing chamber, the metering valve is lifted to admit air past the valve seat, as shown in the right-hand part of the figure. This vacuum is also communicated to the fuel chamber through the aspirating tube, drawing gasoline through it and up the central passage; the latter is expanded in diameter near the top and is then flared out to a large size at the point where the air entering through the vertical holes in the metering valve meets the gasoline and picks it up. The purpose

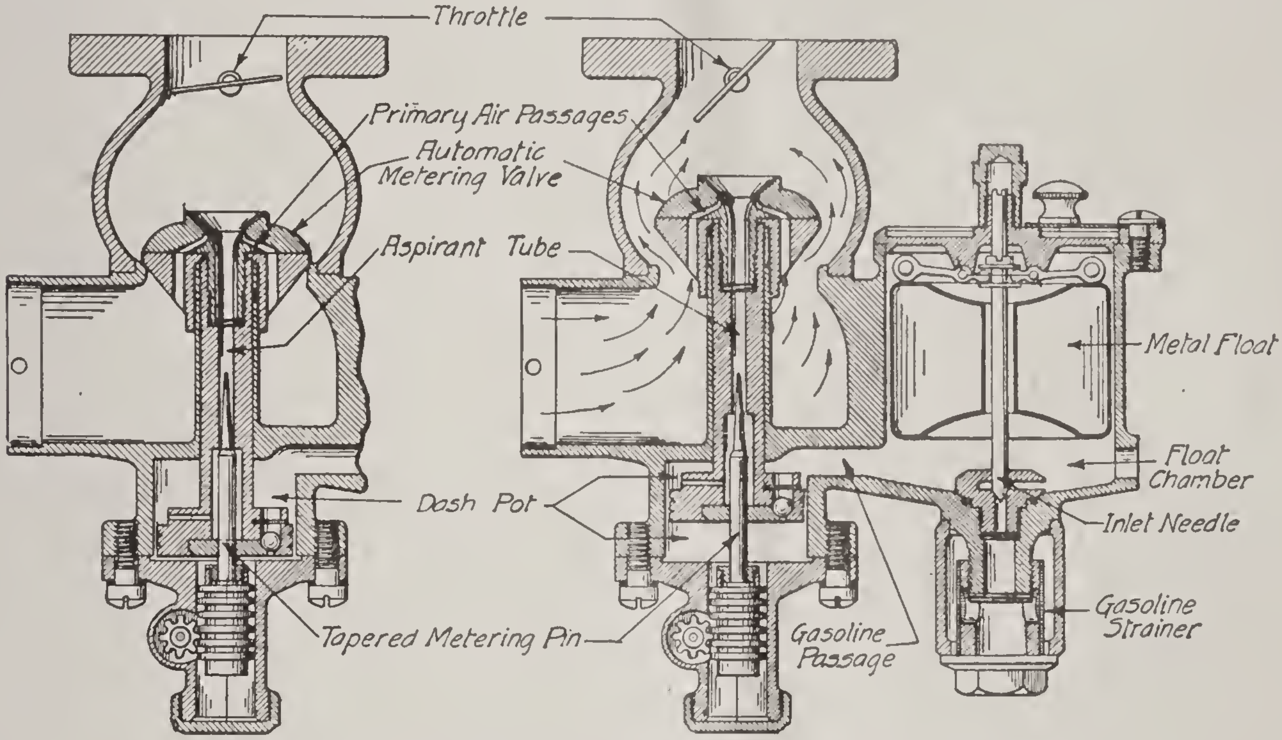


Fig. 113. Sections Showing Construction of Stewart Carburetor
Courtesy of Detroit Lubricator Company, Detroit, Michigan

of this flare is to spread the fuel out into a thin film, which the high velocity primary air picks up readily in minute particles, producing thorough atomization. The high velocity of the air is due to the constant vacuum, this vacuum being determined by the weight of the valve which is always the same. Obviously, atomization is equally good at all speeds.

Starting. This arrangement also makes for easy starting, but this is further facilitated by means of a dash control, which is attached to the metering pin in such a way that, when the plunger (on the dash) is pulled out, the metering pin is lowered away from the metering valve above. This permits more gasoline to be drawn up through the aspirating tube and results in a richer mixture. The dashpot arrangement prevents rapid fluctuations and also makes the metering valve slower to respond than the fuel valve; in this way it produces a gasoline lead over the air which gives good acceleration.

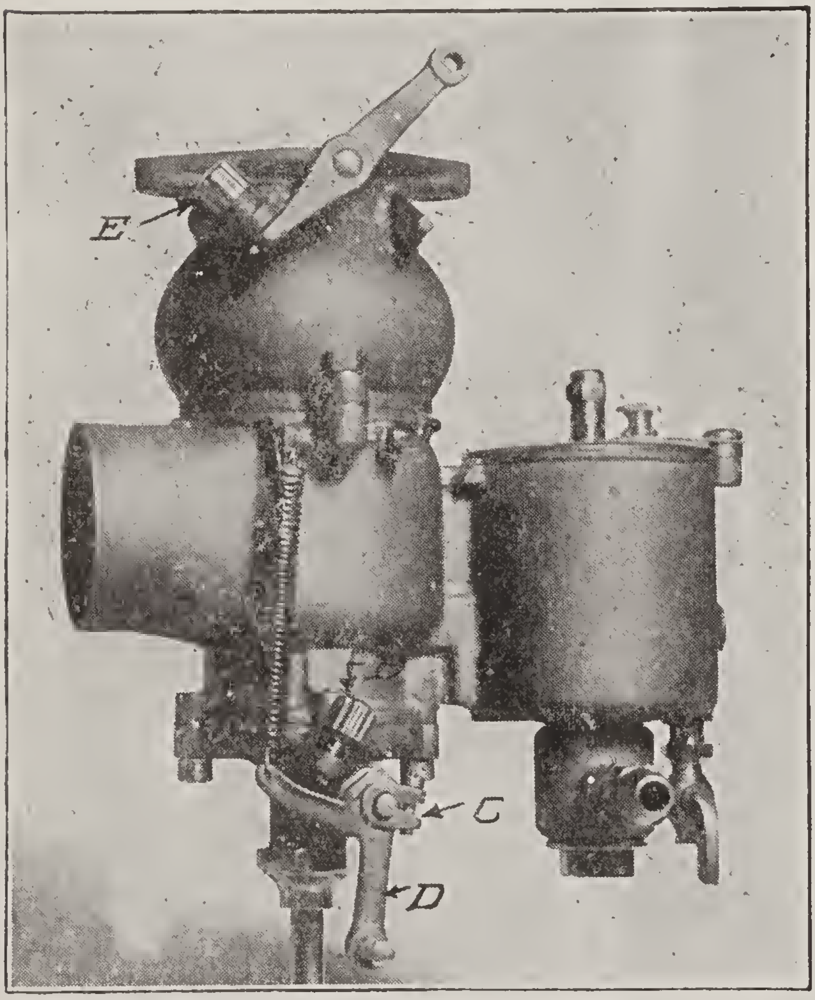


Fig. 114. Exterior of Stewart Carburetor, Showing Adjustments
Courtesy of Detroit Lubricator Company, Detroit, Michigan

The higher the metering valve lifts in response to engine suction, the greater will be the opening around the metering pin, which permits more gasoline to be drawn up; therefore, as the suction varies and the metering valve moves up and down, the volume of air and amount of gasoline must always increase or decrease in the right ratio, automatically giving the right proportions in the mixture at all speeds.

Adjustment. The Stewart has but one adjustment. This consists of the lowering or raising of the tapered metering pin, thereby increasing or decreasing the relative amount of gasoline admitted to the mixing chamber in response to the movement of the metering valve. This movement is produced by the rotation of the small gear *A*, which engages with a rack on the lower end of the tapered metering pin. This gear is rotated by means of a flexible-wire (Bowden) connection to the dash control. The limit of this motion, as well as the normal position of the gear, is governed by the setting of the adjusting, or stop, screw *B*, shown in the external view, Fig. 114.

This screw can be turned either way; turning it to the right lowers the position of the metering pin, admitting more gasoline; and turning it to the left raises it so that less fuel is admitted. A wider range of adjustment than this stop screw affords can be had by releasing the clamp *C* of the pinion-shaft lever *D* and moving it around to a new position on the shaft. This adjustment, however, is not recommended except for expert repair men.

With the motor idling the adjustment should be made by moving the screw up and down, that is, out and in until the motor runs smoothly. This adjustment must be made with the dash control pushed all the way in. When this simple adjustment is made correctly, the device is practically automatic from that time on. A stop screw *E* on the throttle lever is movable and affords the equivalent of a limited adjustment, for it can be set to give a smaller and smaller opening and thus slower and slower idling. It also has an influence on the maximum opening which influences the highest speed.

Johnson Carburetor. The Johnson carburetor, of which a section through Model "D" is shown in Fig. 115, is one of the newer designs to be placed on the market. It is a simple form, with a concentric type of float chamber *A*, above which is a simple cylindrical mixing chamber *B* containing the air-regulating device. It is surrounded by a hot-air jacket *C*, which warms the mixing chamber and furnishes the primary air supply. This is composed of the strangle tube *D* and air controlling sleeve *E*, with a lift plate *F* suspended from this sleeve in the strangle tube.

Operation. Gasoline enters the float chamber from above, in the usual way. It enters the spray nozzle through the cross-hole *G*, then rises inside this and passes the tip of the needle *H*, where it continues out through the nozzle point into the lower part of the mixing chamber. The fuel issues as a fine spray into the strangle tube *D*, which is conical in shape. In the mixing chamber is a sliding brass sleeve *E*, which moves up and down according to the engine suction and carries the lift plate *F* which is just above the outlet from the spraying nozzle. Warm air enters the air inlet *I* and finds its way around the chamber *C*, some of it reaching the passage *J* below the lift plate and strangle tube. Here it picks up the fuel from the nozzle and impinges it against the lift plate to break it up into finer particles. In addition, the rising air and fuel raise the plate and with it the sleeve *E*, allowing more air to enter around the bottom of the sleeve. By this arrangement, the current of air is divided and forms both the primary and the auxiliary currents. The latter current is varied to suit the engine demands by the rising and falling of the sleeve. This movement of the sleeve automatically proportions the air and gas to the demand, for, in rising, the lift plate is drawn away from the nozzle tip, and more fuel is allowed to flow out.

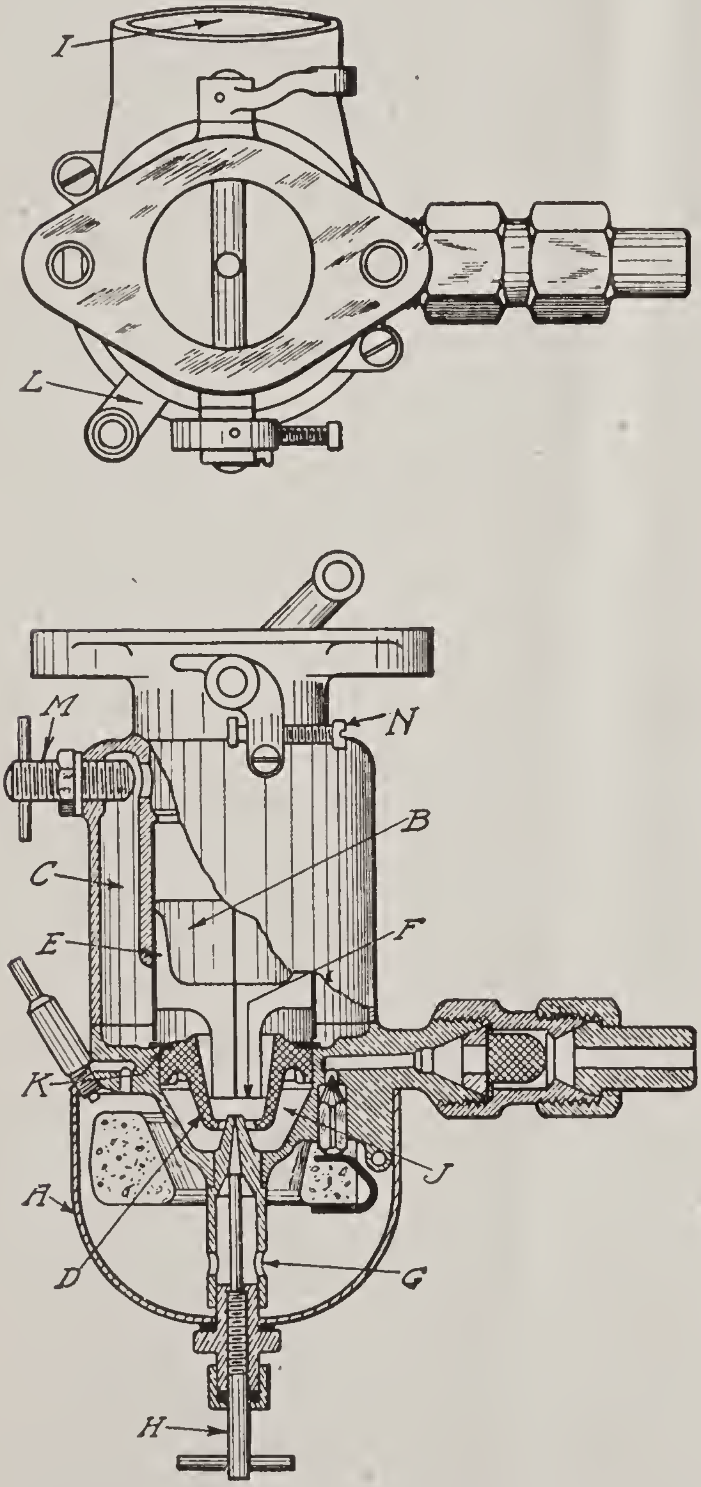


Fig. 115. Top View and Section of Johnson Carburetor, Model "D"

On top of the strangle tube rests a flat choker plate *K*, which is capable of being turned around. There are holes in this to correspond with the holes in the strangle tube through which the primary air passes down to the lower side. In rising again, it picks up the fuel spray. A lever *L* extends through the outside of the carburetor and is connected up to the dash control. This lever controls the choker plate which can be moved around to cover or uncover the air holes and give more or less primary air as the device needs it. Thus, the low-speed screw *M*, the needle valve, and the stop screw *N* on the throttle shaft constitute the adjustments.

Adjusting the Johnson. The function of the low-speed screw is to admit or to cut off the small amount of air supply to the upper part of the mixing chamber as the motor demands; this screw is to be adjusted only with a closed throttle, retarded spark, and the motor idling. The motor should be hot. This is an idling adjustment, designed to supply additional air through the opening *O*, the need for which is caused by the sleeve *E* being in its bottom position and thus cutting off the supply, which is available later when the sleeve has risen and in so doing has formed the annular air passage.

The spray needle *H*, adjusted by the external handle, takes care of all other throttle positions and speeds by admitting more or less fuel. To adjust it, turn the low-speed screw and spray needle to their seats and set the throttle-lever stop screw to approximate the correct closed position. Open the spray needle one and one-half turns. Start the motor, and when it has warmed up, place the spark lever in the fully retarded position; then open the throttle quickly, and if the motor does not back-fire, the mixture is slightly rich and the spray needle should be closed by turning to the right about one-eighth of a turn. Again open the throttle quickly and repeat until the motor does back-fire; this will determine a lean mixture. Open the needle slightly to correct the mixture, which will give the correct adjustment on high and intermediate speed. Adjust the throttle stop screw until the desired idling speed, or about 240 r.p.m., is secured. If the motor does not fire continuously and run smoothly, the low-speed mixture is too rich and is corrected by backing out the low-speed screw *M* until sufficient air is admitted for smooth even firing. Then lock it with the lock nut. If this last adjustment has increased the speed of the motor, restore the idling speed by unscrewing the throttle stop screw *N* slightly. If necessary, reset the low-speed screw, as both of these have to be adjusted in combination.

Dash Control. This controls the choker plate, which acts as a choke to the nozzle by reducing the supply of primary air. After the motor has been warmed up, this should be in the wide-open position. The position for a cold motor, approximating the closed position, will be determined by experience. It is recommended that the motor be choked, that is, the dash control set in the closed position, when stopping. This provides a rich charge for starting. As will be seen from this, the choker plate, with its dash control, is primarily a starting device.

Other Models. This carburetor is made in other models, notably a small one for the Ford car; the essential difference in this being the location of the low-speed screw on top, as it has a horizontal outlet on one side and the warm air inlet on the other. Another large size for eight-cylinder models has a special accelerating device consisting of a fuel plunger operated from the throttle. Still another model is a fixed-needle type in which the nozzle is calibrated for the motor. The adjustment is practically the same for all these.

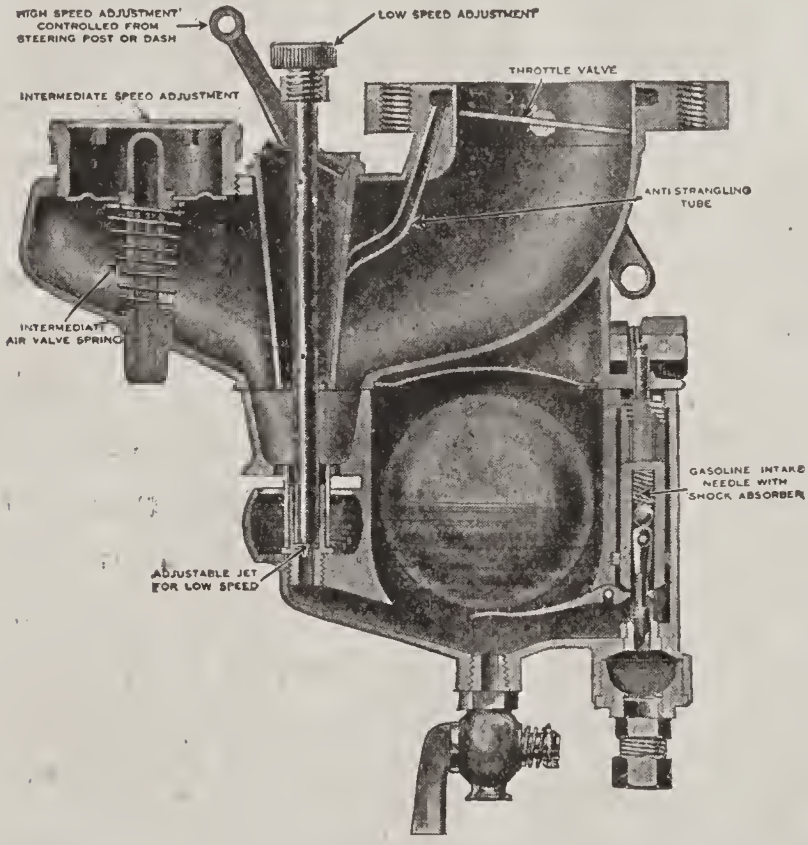

HIGH SPEED ADJUSTMENT CONTROLLED FROM STEERING POST OR DASH
LOW SPEED ADJUSTMENT
THROTTLE VALVE
INTERMEDIATE SPEED ADJUSTMENT
ANTI STRANGLING TUBE
INTERMEDIATE AIR VALVE SPRING
GASOLINE INTAKE NEEDLE WITH SHOCK ABSORBER
ADJUSTABLE JET FOR LOW SPEED

Fig. 116. Section of Carter Multiple-Jet Carburetor
Courtesy of Carter Carburetor Company, St. Louis, Missouri

Carter Carburetor. The Carter carburetor is a multiple-jet device in which, at slow or idling speed, but one jet is furnishing fuel, while at extreme high speed eighteen are operating. These are not jets in the sense that the ordinary carburetor has separate vertical or horizontal jets, as in the Master carburetor, for instance, but they consist of a series of holes set spirally around a central standpipe of fairly large diameter. The action of the device is such that only one is working at low speed, while at high speed the great suction is drawing the fuel up so high in the standpipe that it is issuing from the entire group of 18 holes.

A vertical section through the center of this carburetor is shown in Fig. 116. As will be noted, the bottom of this rests in a tube, or open standpipe, which communicates with the float chamber and is kept filled to the float level with fuel. Just at the top of this tube is the main air inlet. The air enters around the sides of the standpipe and rises vertically along it. Around the upper part of the standpipe is a flaring conical tube, the top of which is closed by a damper. Air enters here and is drawn downward, its amount being controlled by the damper. At the left will be seen the supplementary air valve, a third source of air; this air is also drawn downward, and the amount is adjustable. From this it can be seen that the primary air and the fuel from the first few jets come upward, while the secondary air and the fuel from the additional jets go downward, and that the supplementary air rushes in at an angle where these two meet at the bottom of the U-shaped vaporizing chamber. This produces a constant state of turbulence around the standpipe, which facilitates breaking up and vaporizing the fuel. The fuel passes a butterfly throttle in its passage to the inlet manifold.

For easy starting, a tube (marked anti-strangling tube in the cut) is by-passed around the vaporizing chamber, taking its fuel directly from the well at the left of the float chamber and furnishing it directly into the outlet pipe above the throttle. In starting and idling on the lowest jet, or hole, of the standpipe, the fuel is drawn almost directly from the float chamber. For this reason an unusually accurate float arrangement is necessary, and this is provided by the metal ball float and the needle arrangement with its ball and spring shock absorber. The latter eliminates any possibility of jamming and gives accurate control of the fuel level. The action of the device is very simple, the engine suction drawing the fuel higher and higher in the standpipe as the suction increases, while the same suction draws open the intermediate air valve as soon as the required supply exceeds the capacity of the main air intake. The high-speed air inlet, operated by the damper, is thrown into action from the steering post or dash at the will of the operator.

Adjusting the Carter. By reference to Fig. 116, the adjusting will be made plain. First set the high-speed adjustment with the lever in a vertical position; then turn the knurled button marked low-speed adjustment down, or to the right as far as it will go; next back it off and turn it to the left three-quarters of a turn. Turn the knurled valve ring marked intermediate-speed adjustment to the point where the valve seats lightly, then turn the valve down, or to the right, from eight to ten notches to increase the spring tension. Pull the easy-starting lever, connected with the dash, forward to the position shown in Fig. 119, advance the spark a very little, close the throttle, and start the engine.

Through the medium of the anti-strangling tube, this will furnish rich mixture (almost pure fuel) to the inlet manifold and result in instantaneous starting. Immediately reverse the easy-starting lever which controls the flow of fuel and open the main throttle slightly. By means of the two screws *AA* on either side of the throttle lever, set the throttle valve where it gives the desired engine speed when idling. Move the low-speed adjustment to the left, one notch at a time, until the engine slows down, noting each setting. Now move it in the opposite direction, one notch at a time, until the engine again slows down. Then move the adjustment to a point midway between the two, and the low-speed setting will have been finally fixed. This should not be changed on account of weather or temperature variations.

Set the throttle about one-third open and turn the intermediate adjustment to the left until the engine slows down. Move to the right until a similar decrease in speed is noted, then set midway between the two. This adjustment, when once properly made, should not be changed for weather or temperature changes. After this adjustment has been made, connect the high-speed adjusting lever to the dash or steering-post control so that in the center of its movement the lever on the carburetor is vertical. Drive the car over a level road at about 20 miles an hour, then move the control lever to the point where the engine gives the best results at this speed. At low temperatures, or when the engine is cold, this control should be moved toward the closed position, so as to cut off air and make a richer mixture. At high temperatures and with a warm engine, the best results are obtained with the control wide open. This is the only adjustment which should be varied for weather or temperature variations.

Newer Carter Models. In addition, this company has two newer models, "H" and "L," the principal difference being in the outlets, "H" having a vertical and "L" a horizontal outlet. The former is shown in Fig. 117, which shows both a vertical section and end view. It will be noted that the fuel passes through a strainer into the float chamber, then entering below passes through the high speed jet if the throttle is open and through the small hole in it, and thence through the low speed jet, up the vertical fuel passage, and part passes out into the vaporizing chamber, while part continues on up into the inlet manifold above or beyond the throttle. The action of these two jets is evident from their construction and this description.

Adjustment of Carter "H" and "L" Models. The adjustment of these two models is similar, this being controlled ordinarily by setting the throw of the throttle lever in the proper position for idle engine speed. This is done by means of an adjusting screw, which is provided with a lock screw to hold it when adjusted. This lever should be so set that with steering wheel quadrant lever and accelerator closed, engine will turn over at normal idling speed of 250 to 300 r.p.m. Model "L" has an additional idling adjustment, consisting of a small screw which controls the amount of fuel passing out into the manifold beyond the throttle. The only other normal adjustment is the connection of the dash control wire to the carburetor choker lever; shortening this will cause the air shutter to close more tightly, lengthening it, not as tightly.

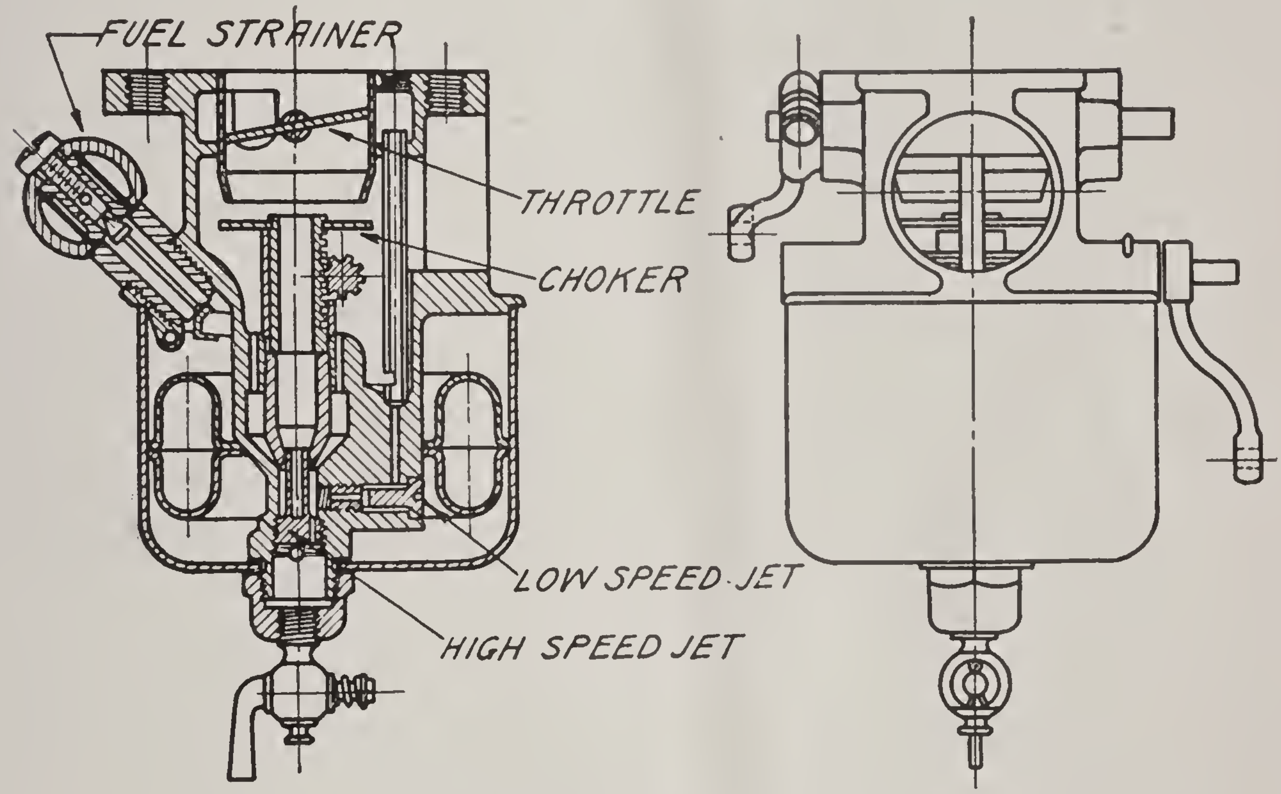


Fig. 117. Carter Model "H" Carburetor with Vertical Outlet
Courtesy Carter Carburetor Company, St. Louis, Missouri

H. & N. Carburetor. This device, shown in Fig. 118, uses no springs, yet two adjustments are provided. Fuel enters from below, into a nozzle, the metering needle projecting down into this, somewhat the same as in the Newcomb previously described. This needle is incorporated in or carried by a movable air valve, which is gradually raised permitting more air to enter as the engine speeds up and the suction becomes greater. In its lowest position, it governs the amount of air entering at idling or low speeds, and this low position is adjusted by raising or lowering a threaded ring upon which it seats. It is fitted into the body of the device in such a way that an air chamber is left above it, between its upper surface and the body. This enclosed air chamber is fitted with a vacuum relief valve, which constitutes the high speed adjustment. Opening the relief valve permits the air valve to rise higher at high motor speeds, and this higher valve position admits more fuel through the fuel nozzle, and more air through the auxiliary air ports which it uncovers. Thus, the device is wholly automatic in its action.

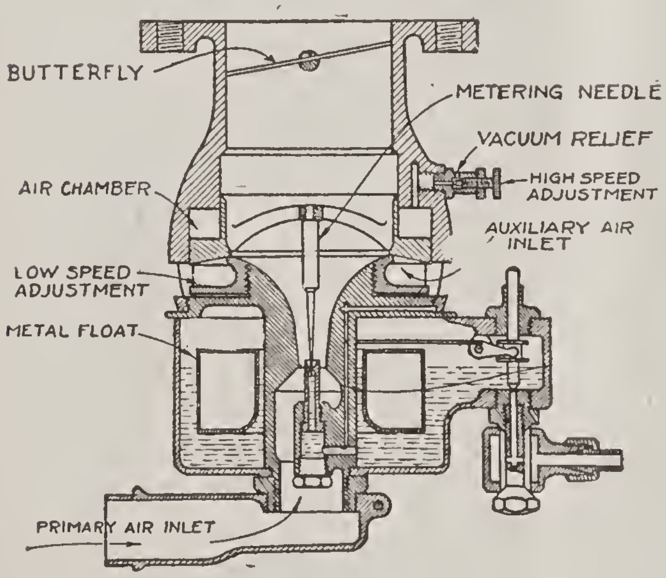


Fig. 118. Section Showing Simplicity of H. and N. Carburetor

Courtesy H. and N. Carburetor Company, Long Island City, New York

Adjustment of the H. & N. These two adjustments are utilized in the normal way. The engine is started and heated up, then the low speed adjustment is operated through its milled outer edge, until the idling and low speed performance is satisfactory. The engine is then speeded up, and the high speed adjustment varied to produce maximum speed and power.

Tillotson Carburetor. In a general way the Tillotson carburetor resembles a long U-shaped tube laid upon its side, with the air entering the upper branch, passing around the curve and out to the motor at the end of the lower branch. In the latter near the delivery end, are placed the two jets, first the secondary, next the primary. A pair of flexible reeds are arranged within the passage in such a way that they entirely enclose and shut off the secondary when they are closed, but do not interfere with the primary. The reeds are opened by the suction of the engine, so that the primary nozzle furnishes fuel at all engine speeds but is the *only* one in operation at the slower speeds, and is the only one that is adjustable. The secondary nozzle gives the added fuel for high engine speeds and is in operation at these higher speeds only.

Not all the Tillotson models have this exact shape, many being more of an L shape. The float chamber location varies with the different models in some being below the U (or L) tube, in others at one side.

Adjustment of the Tillotson Carburetor. As has been stated the primary nozzle only is adjustable. The company recommends that this be done with unusual care, and very slowly. With the motor running and well warmed up, turn the adjusting handle up to the right until the motor commences to slow down from lack of fuel, then turn it back about one-eighth of a turn. Avoid getting the mixture too rich. Fig. 119 shows Model "C" 85-6 in partial section and the reed action.

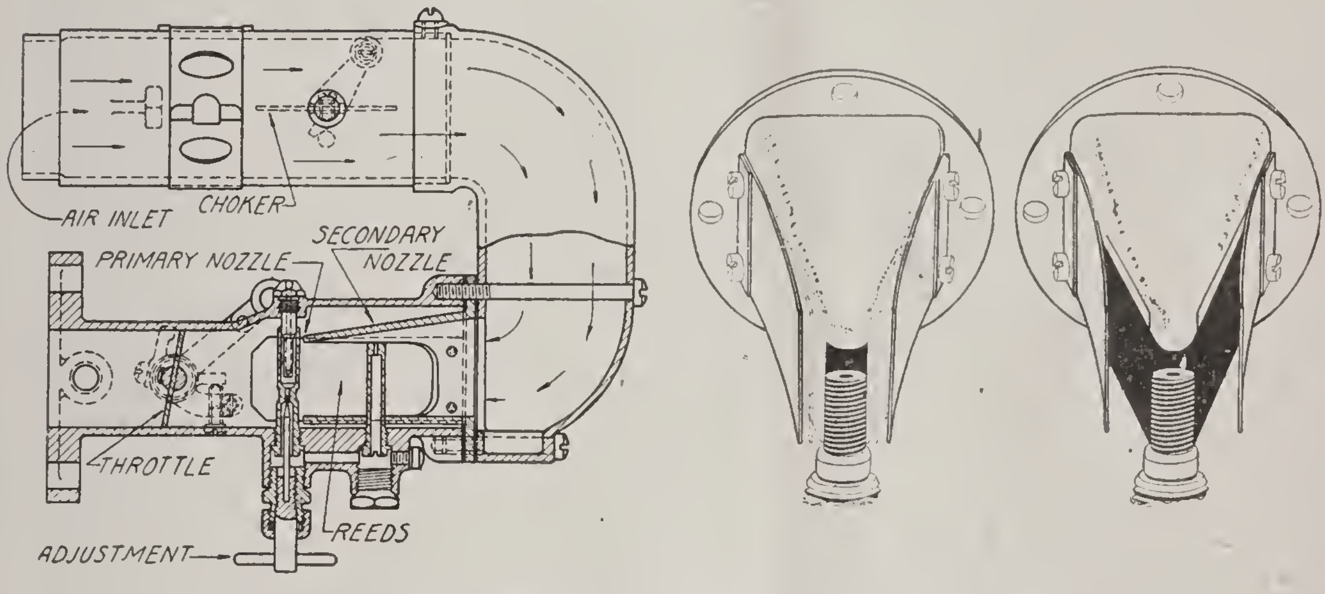


Fig. 119. Tillotson Model "C" Carburetor, Showing Steel Reeds
Courtesy Tillotson Manufacturing Company, Toledo, Ohio

Knox "F" Carburetor. In the Knox carburetor, made by the Camden Anchor-Rockland Machine Co., the automizing valve takes the form of the usual mushroom or poppet valve of engines, the stem being drilled out and the atomizing openings being drilled radially and horizontally into the mushroom or upper part of this. This gives a radial series of sprays of fuel into the enlarged mixing chamber, which is heated externally by warm air, and receives its air from below through a large opening. The combination of this widely diffused spray, the large air opening with the air entering at the widest extremity of this spray and the heating should make for complete vaporization. The device is shown in section in Fig. 120.

Adjusting the Knox. The setting of the choke valve can be varied slightly with some effect on the running of the motor, but the only real adjustment is that of the needle valve. Closing the choke valve cuts down the air and produces a richer mixture. When three-fourths to fully closed, it primes the motor through the priming tube, and should be closed only on starting for this reason. The metering needle regulates the flow of fuel as the atomizer rises and falls. Before the carburetor is attached, this should be screwed up until it lifts the atomizer off its seat. Then it should be unscrewed three or four full turns to give a starting setting. Put the carburetor on the motor, start it and run until warm, then adjust working the choke valve up to full opening and the throttle down to lowest idling speed, until the motor runs smooth and right. This done, open the throttle and try the running at full throttle. If properly adjusted and the motor does not pick up and show more power, a larger needle must be inserted, and if the motor acts starved, insert a smaller needle.

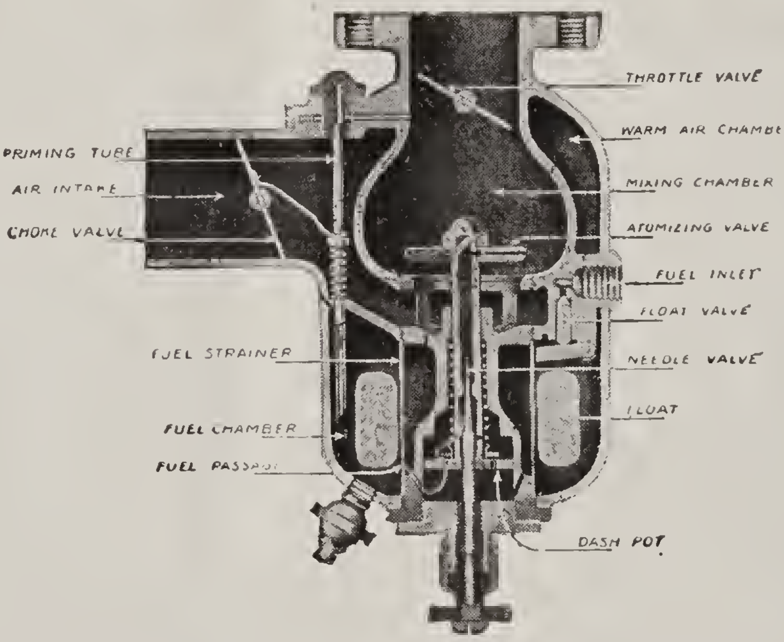


Fig. 120. Section through Knox Model "F" Carburetor
Courtesy Camden Anchor—Rockland Machine Company, Camden, Maine

Sunderman "Nitro" Carburetor. In the Sunderman "Nitro" carburetor a mushroom jet and an air bypass are used in conjunction with a floating Venturi to attain the desired vaporization results. This is shown in Fig. 121, which indicates a section through this simple carburetor at high, medium and low speeds. These illustrations make the construction, and other details self-evident.

Adjusting the Nitro. There is but one adjustment provided, modification of the suction on the jet by a screw which governs

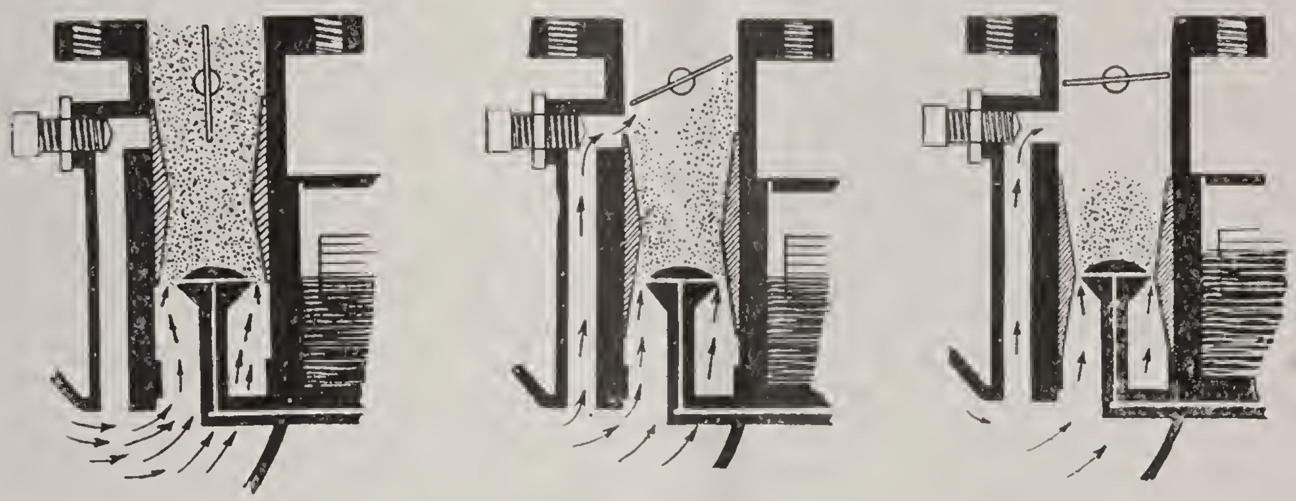

High Speed
Medium Speed
Idling

Fig. 121. Sketches Showing Operation of Venturi in Sunderman Nitro Carburetor
Courtesy Sunderman Corporation, Newburgh, New York

the size of the air passage where it makes the right angle bend. This adjustment reduces the suction of the nozzle at lower speeds and thus, the flow of fuel, and prevents the Venturi rising too rapidly. Thus, it is adjusted only for idling and slow speeds.

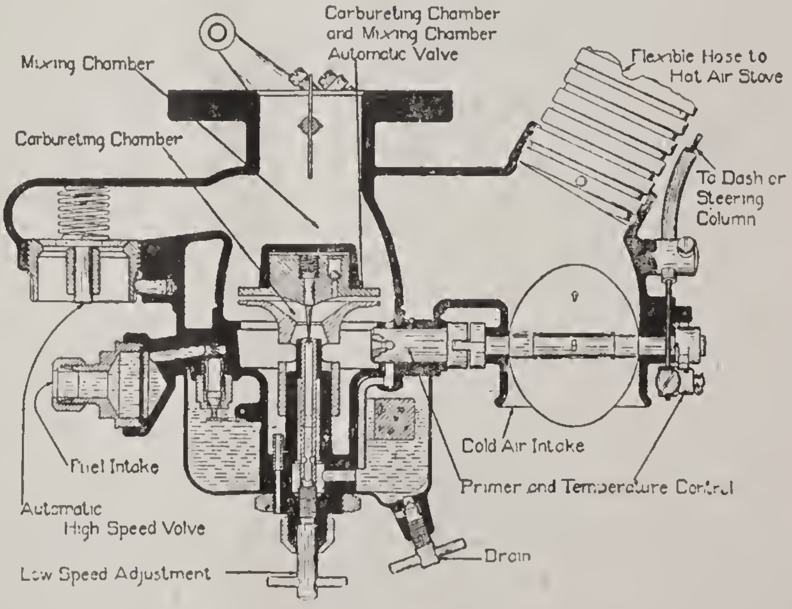


Fig. 122. Section through Shakespeare Carburetor
Courtesy Shakespeare Company, Kalamazoo, Michigan

Shakespeare Carburetor. The feature of the Shakespeare carburetor, shown in section in Fig. 122, is the automatic valve which forces a positive mechanical subdivision of the fuel and simultaneous mixing of the air at a low vacuum. As will be noted in the cut, this is accomplished by giving the fuel an outward flow, much the same as the mushroom drilled valve of the Knox or the Nitro, air being led into the center of this and around the outside at the same time.

Adjusting the Shakespeare. The makers call this a one-adjustment model, the nozzle being adjustable toward or away from the needle, and this constituting the low speed adjustment, which is manipulated in the usual way. There is, however, a high speed air valve for the extremely high or racing speeds, and this also is adjustable.

Packard Carburetor. The carburetor used on the Packard twin-six (twelve-cylinder) cars is shown in section in Fig. 123. The inlet manifold, or rather the pipe which leads in both directions to the manifold proper, is seen at the top at A. It will be noted that this is water-jacketed, the water space being at the top. The float arrangement is of the usual type, with a metal float which supplies fuel to a small well B at the base of the single-spray tube C. This has a flared end located in the center of the Venturi. When the air from the air horn D passes the air shutter E, it picks up the fuel and carries it up into the vaporizing chamber F. The primary air shutter is normally open but not in use. It is operated by a hand wheel on the control board which also operates the auxiliary air valve G. By turning this

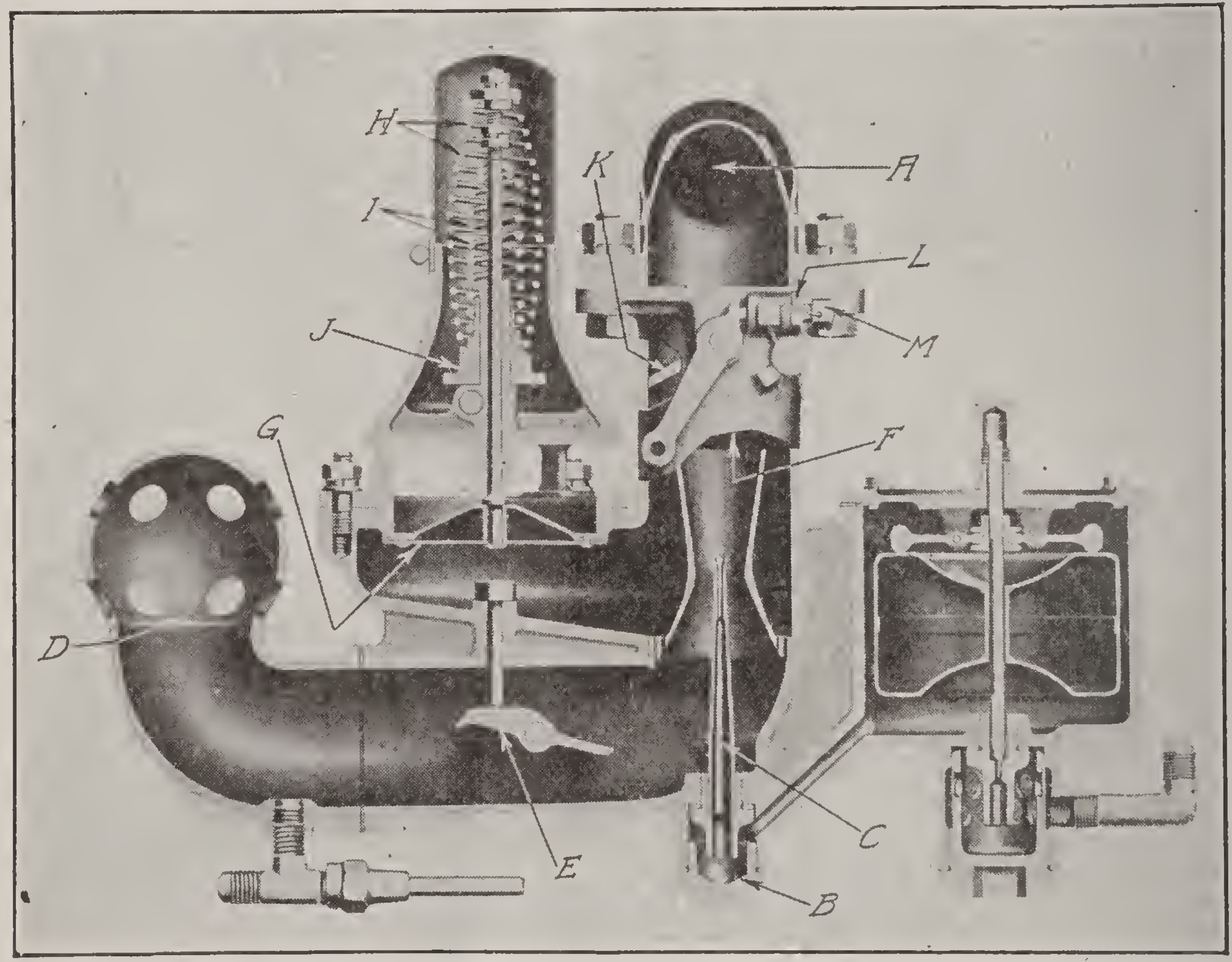


Fig. 123. Section through Packard Twin-Six Carburetor
Courtesy of Packard Motor Car Company, Detroit, Michigan

clear over to the position marked choke, the air intake is closed, and a rich mixture is drawn in for starting. After that, the hand wheel should be set back toward the position marked air which opens the air intake.

The auxiliary air valve is controlled by the springs *H* and *I*. These are adjusted so that the valve opens very slightly at low speed, but more and more as the speed, and consequently the suction, increases. The air enters around the outside of the Venturi, communicating with the mixture only above the top of the latter where the real vaporizing chamber commences. The tension of the springs is varied by means of the adjusting nuts at the top and by the adjusting cams *J*. The cams are connected up to the air-valve hand wheel which is turned toward gas to provide a richer mixture and toward air for a leaner mixture. If the wheel is turned too far toward air, spitting back may result; and if it is turned too far toward gas, the result may be irregular running and overheating. The throttle *K* is of the butterfly type and regulates the quantity of mixture allowed to pass out, not its quality. An adjustable stop holds this valve open slightly and allows a small amount of mixture to pass, even when the hand throttle is entirely closed. This minimum amount is for slowest running, or idling, only. To increase it, loosen the check nut *L* and screw the stop *M* forward. To decrease the minimum speed, screw the stop backward.

Adjustments. Aside from those described previously, the Packard Company advises against making any adjustments as it prefers to have this done by its own men, who have had extended experience in adjusting the motor and carburetor combinations.

Cadillac Carburetor. A section through the latest Cadillac carburetor, which is a very simple device, is shown in Fig. 124. Fuel enters through the pipe *A* at the bottom, passing on to the well *B*, and thence to the float chamber, through the vertical pipe *C* and the float valve *D*, which are operated by the float *E*. This float is concentric and is hinged on one side of the float chamber. Below the float chamber is another chamber, or well, *F* which is supplied from it. Through the opening in the side of the nozzle *G*, this well in turn supplies fuel to the nozzle *H*, the fuel being drawn out at the top into the Venturi chamber *I*. At the left will be seen the air valve *J* as well as the scoop of shield *K*, which assists in drawing in the required volume of air. This air reaches the passage *L*, whence a portion is drawn downward around the outside of the Venturi *I*, through the passage *M*, and around the bottom of the tube, then upward. There it mixes with the fuel spray, vaporizes it, and carries it up into the main vaporizing chamber *N*, where additional air comes in from *L*, and the mixture passes on up, through the throttle valve *O*, into the inlet manifold.

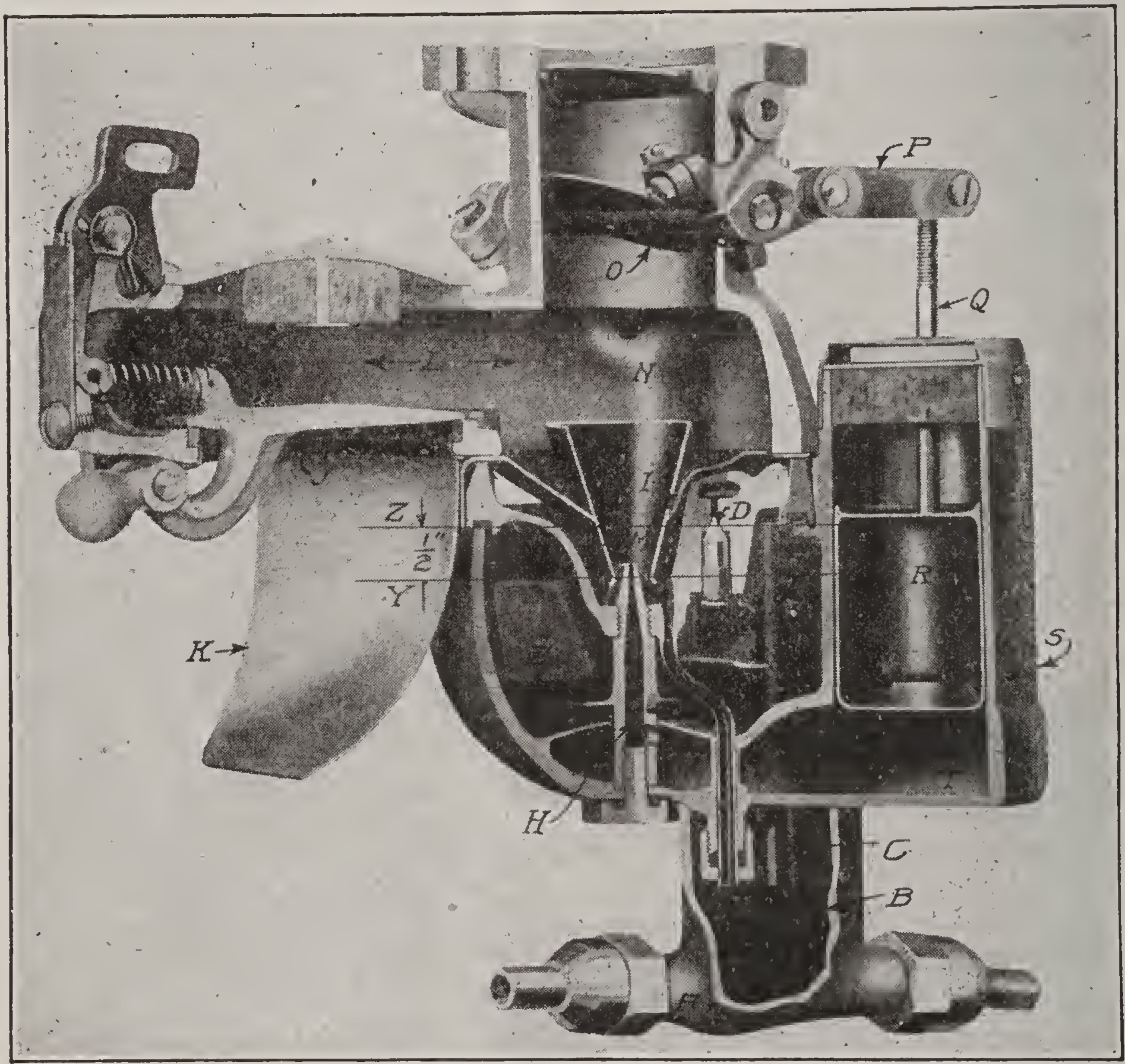


Fig. 124. Section through Cadillac Carburetor Used on Models 53, 55 and 57
Courtesy of Cadillac Motor Car Company, Detroit, Michigan

On a lever *P* attached to the throttle valve shaft is hung the connecting rod *Q*, by means of which it is attached at its lower end to the piston *R*. This works up and down in the chamber *S*. Its lower portion, or well, *T* is full of fuel and communicates through passage *U* with the well *F* and the nozzle *H*. When the throttle is opened, the plunger is forced into the gasoline in the carburetor bowl, and fuel is thus forced through the hole *G* up to the nozzle *H*. When the throttle is opened quickly, this acts to supply the needed fuel. When the throttle is opened slowly, the plunger has practically no effect. This plunger has an influence on starting, as will be explained.

Adjustments. Carburetors are factory set and should need no adjustment ordinarily, but for different atmospheric conditions a slight change in the air-valve spring may be needed. In the exterior view, Fig. 125, this is altered by turning the screw *V*. In case the carburetor really needs adjustment, proceed as follows: Open the throttle lever on the steering wheel about two inches, place the spark in the driving range and start the motor; run it until the water jacket on the intake pipe is hot; then move the spark lever to the extreme left on the sector and the throttle lever to a position which leaves the throttle slightly open, and adjust the air-valve screw *V* to a point which produces the highest engine speed. Turning this screw clockwise increases the proportion of gasoline to air in the mixture, that is, makes it richer; while turning it counter-clockwise decreases the proportion of gasoline, that is, makes it leaner.

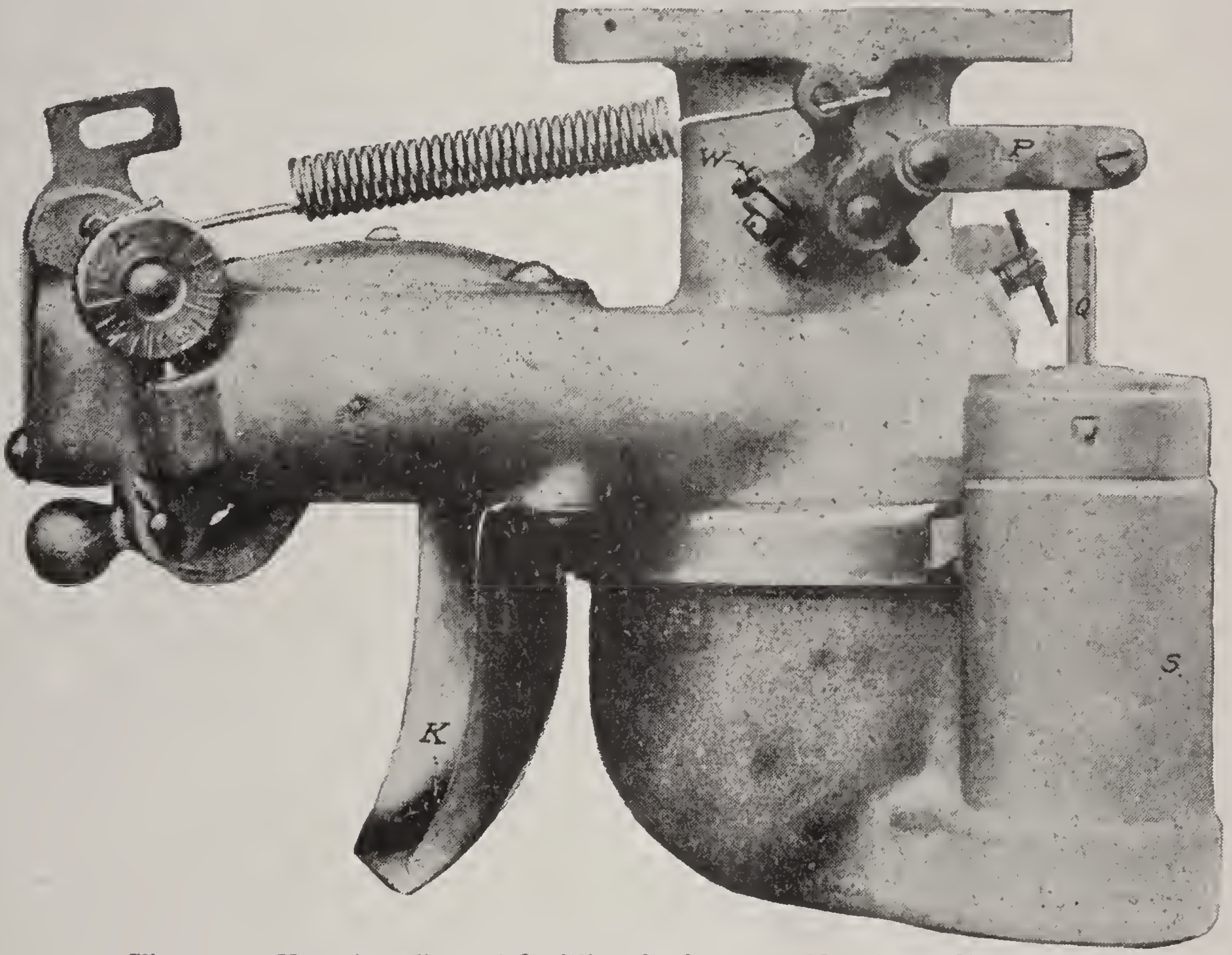


Fig. 125. Exterior View of Cadillac Carburetor, Showing Adjustments

Close the throttle by moving it to the extreme left on the sector, and adjust the throttle stop screw *W* to a point which causes the engine to run at a speed of about 300 r.p.m. The spark lever should be at the extreme left when this adjustment is made. With the spark and throttle levers in this same position, adjust the air valve screw *V* again to the highest motor speed. Open the throttle until the shutter attached to the right-hand end of the throttle shaft just covers the slot in the carburetor body (the other side of the carburetor is not shown in either view). Then adjust the screw *X* to the point which produces the highest engine speed or to a point where the engine slows down slightly from a lean mixture. This screw also works clockwise to give a richer mixture and counter-clockwise for a leaner one. During very cold weather, it will be found advisable to turn this screw farther in a clockwise direction to give a slightly richer mixture.

The rod *Q* from throttle arm *P* to the fuel plunger is adjusted closely at the factory and should need no change unless the carburetor is disassembled. When reassembling, the rod should be adjusted so that its upper end is flush with the upper face of the arm *P*. When the carburetor has been used for a long time, there may be slight wear at the point of the inlet or where the float needle *D*, Fig. 121, rests on its seat. If this should occur, the height of the fuel in the carburetor bowl will rise. To determine whether the float is set properly, remove the carburetor from the engine and the bowl from the carburetor. Then measure the distance from the upper surface of the float to the metal surface above it, as indicated at *Y* to *Z*. This is measured best with the carburetor inverted and should be exactly $\frac{1}{2}$ inch. If more, or less, the setting may be corrected by slightly bending the arm to which the float is attached.

Starting. In cold weather, when the engine will not start immediately, it is not advisable to continue cranking the engine over and over. Instead, open and close the throttle rather quickly once or twice, no more, with the throttle lever on the steering wheel or foot accelerator. This action raises and lowers the throttle pump attached to the throttle-shaft arm, as previously explained, thus raising the level of the fuel in the float chamber so that it is more easily drawn up. If pumped more than once or twice, too much fuel will be forced up, and this is just as bad as too little.

Oxygen-Adding Devices. There are now upon the market a number of devices for assisting carburetion by furnishing an additional source of oxygen. These are not carburetors in themselves, in that they do not handle any fuel, consequently they must be used in addition to some standard carburetor, furnished with fuel in the regular way. The desired result is obtained in a number of different ways, as for instance the direct injection of water, which the heat of combustion is supposed to break up into its components hydrogen and oxygen. The hydrogen is a fuel itself, and the oxygen assists the vaporized gasoline fuel to burn better and more completely. Steam is but a variation of this, the exhaust heat being used to create this from water furnished by a special tank. When equipped with valves to control water passage or steam emission, these constitute the only adjustment.

KEROSENE AND HEAVY FUEL CARBURETORS

Need for Heavy Fuel Carburetors. As has been mentioned several times previously, and explained elsewhere in detail, the lighter, more volatile grades of gasoline are not available in sufficient quantities to supply the present demand. Consequently, the fuel now carries a considerable quantity of what was formerly sold as kerosene and also under other names. At that, the fuel sold is still much lighter than kerosene—of which tremendous quantities are available—as well as other heavy fuels, notably benzol in England, where kerosene is called paraffin. To develop a carburetor which would handle these cheaper but heavier and more available fuels has been the aim of many inventors and a vexing problem for carburetor manufacturers.

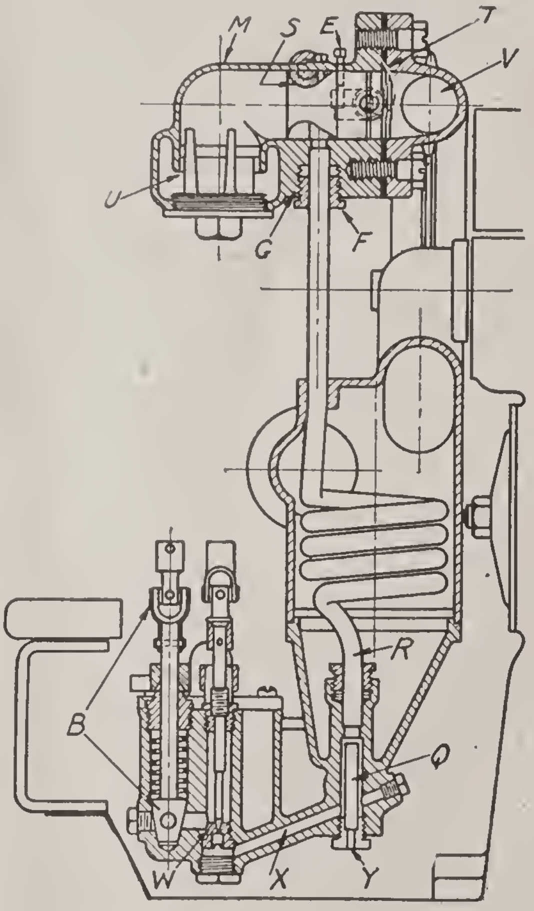


Fig. 126. Section through the Holley Kerosene Carburetor

Holley Type. A firm, the Holley Company, which has devoted much time and study to this problem, has developed the device shown in Fig. 125. While this is not offered as perfect, even by its maker, who is still working on this problem, it has been found to do these things: cut the fuel cost over 50 per cent; increase the power 5 to 8 per cent; save almost one-half of the engine lubricant; give less spark-plug trouble and less carbonizing; and give a greater mileage to the gallon. It also has these deficiencies: requires the use of gasoline for starting; and necessitates a material reduction in compression pressures.

This device as shown in Fig. 126 has two float chambers, one for gasoline used in starting, the other for the kerosene or heavier fuel. The shifter valve *B* determines which fuel flows to the adjusting needle valve *W* and through a jet where a minute quantity of the total air needed in the form of an air blast atomizes it. Then it is carried up through the tube *R* situated in the exhaust manifold and heated by it. Then it enters the main mixing chamber *M*, where the main air supply enters through *U*, this opening being governed by the suction of the motor and the throttle valve opening. From here it is drawn in through the intake manifold *V* in the usual way.

Adjustment Holley Kerosene Device. In general, the motor is always started on gasoline, which is used purely for starting and warming up the motor, when the change over to kerosene is made. The adjustments should be made on the basis of kerosene, even though it seems somewhat rich when running on gasoline. Set screw *E*, which limits the throw of the throttle lever, should be adjusted so the motor runs at proper idling speed when the hand throttle lever is in the closed position.

Holley All-Fuel Carburetor. Another Holley device is intended for the use of all kinds of fuel, heavier than our so-called gasoline. This is shown in Fig. 127, which presents a sectional view and explains all the parts as well as the operation. It consists of a simple spraying device with an air valve which sprays the heavy fuel, adds a very small amount of air to it, and then forces this mixture through a vapor tube, consisting of coils of thin-walled pipe surrounding the exhaust pipe. The exhaust heats the walls enough to completely vaporize any fuel that will evaporate below 600° F. This heater, rich, dry gas mixture is then returned to the main body of the carburetor where additional cold air is admitted to convert it into a perfectly combustible mixture. It then passes through the throttle and inlet manifold to the engine. Like the Holley kerosene carburetor just described, this starts on gasoline, and is switched to the heavier fuel as soon as the motor is well warmed up and the exhaust heat begins to be available.

Aside from the usual throttle and air valve limit stops, there really is but one adjustment.

Adjusting the All-Fuel Carburetor. The principal adjustment on this device is the idling. The figure shows this near the bottom, it consisting of a valve with a milled outside head which controls the inflow of air. Sufficient air is drawn past this for idling and it lifts to admit more air for higher motor speeds. The valve is regulated so that in its lowest position just enough air passes to give a satisfactory idling speed. An arrow on the top indicates this. When the valve is entirely closed, as indicated by the arrow, the air is practically shut off and the mixture is richest.

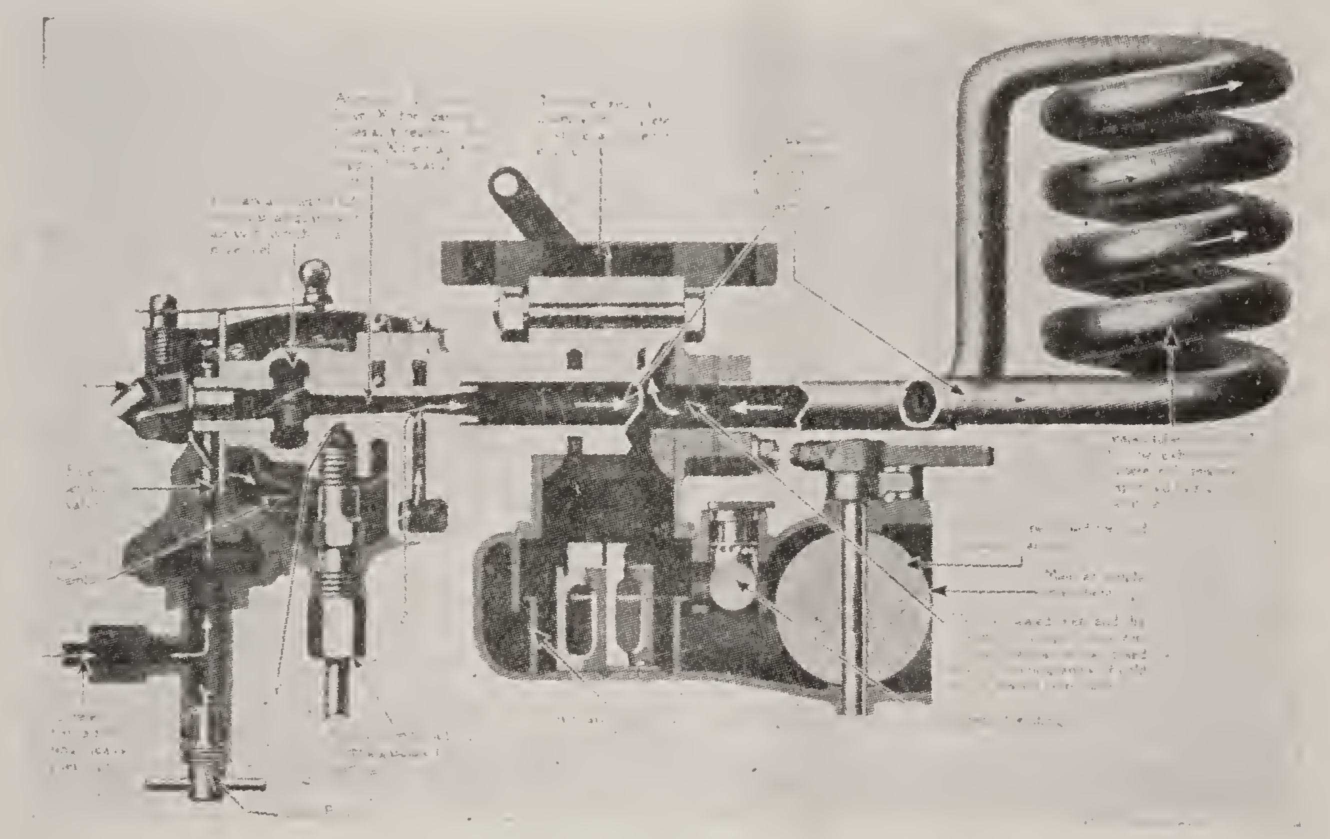


Fig. 127. Section Showing Construction of All-Fuel Carburetor
Courtesy Holley Brothers Company, Detroit, Michigan

The air intake is fitted with a choke throttle and the tightness of closing this can be regulated by a stop screw. Similarly, the main throttle can be regulated by means of a stop screw, to vary its tightness in the closed position. The only other changes or adjustments would be to change the atomizer for one with different sized jet holes at Y and Z as well as the primary air inlet.

Foreign Kerosene Carburetors. A large number of firms in different parts of the world have worked on this problem of kerosene vaporization. In Germany, the following have done so, and in solving this each has been obliged to develop his own vaporizer: Daimler; Swiderski; Maurer; Adler; Sleipner (boats mostly); Deutz; Banki; Neckarsulmer (motorcycle); Koerting (fuel injection); Kämper; Diesel (fuel injection); Capitaine (boats mostly); Gardner; Dufaux (Swiss motorcycle); and others. Space prevents a description of these, the list being given simply to show that kerosene as a fuel has attracted wide attention.

In France the same is true; the Aster device, for instance, having been so very successful that it is now made under license in both England and Germany.

In England the Binks, with two jets, is designed to use 20 per cent gasoline and 80 per cent kerosene after starting. The Hamilton Bi-fuel has two float chambers, two nozzles, and other duplicate features. This is designed for a 44 gasoline (petrol) and 56 kerosene (paraffin) mixture; on such a mixture, a test of a bus engine showed equal (rated) power at 890 r.p.m.; 1 horsepower more at 1050; almost 3 more at 1275; and at its highest speed 1375 r.p.m., 3 horsepower more, maximum output. The Kellaway has two fuel leads, but these use a common jet. The Morris uses forced feed with a constant air pressure of 4 pounds per square inch on the fuel tank; this is supposed to minimize variations in fuel flow, and thus, as pointed out in the description of the Browne, minimize variations in the output. The Southey ignites part of the fuel to create heat with which to vaporize the balance, delivering to the cylinders a fixed gas which is heated. The Edwards has been described. In the Notax the fuel spray, as it enters the vaporizing chamber, is forced to strike the lower hot surface of the exhaust-gas passage, which not only encircles the chamber but has a passage right through the middle of it. In the G. C. (English and American), the vaporizer complete replaces both carburetor and muffler. It is constructed to utilize all the heat in the exhaust gases for vaporizing the kerosene, which then is led up to the engine, and auxiliary air added just before it enters the manifold. This has a separate small gasoline carburetor for starting and a special float chamber for the kerosene. In America, the Knox employs an arrangement in which a gasoline by-pass around the entire carburetor is used for starting, while the exhaust heating concerns the fuel at the bottom of the device only. The Secor type is used on the Rumely tractors. The Hart-Parr Tractor Company and a number of other builders of tractor, marine, and stationary engines have been more or less successful in vaporizing kerosene so as to use it advantageously.

Master Carburetor. The Master device, previously shown and described, was designed primarily for the extra heavy fuels, or the residuum in the distilling process called distillate, which is heavier than kerosene and has heretofore been considered a waste product. The Master has utilized this successfully in actual service for more than four years. In addition, it will handle kerosene, alcohol, and other heavy fuels, as well as mixtures of all these with one another and with gasoline.

Like the Master, the Miller also previously described as a gasoline device, was designed originally for the extra heavy fuels of the coast, so that it must be considered as a heavy fuel carburetor. This is partly true of the "H and N," which was designed originally for heavy fuels, the present form embodying the most successful details of the heavy-fuel device.

Bennett Carburetor. The Bennett device, Type "C" which is shown in section in Fig. 128, is intended for kerosene, alcohol, distillates, or other heavy fuels, but by a simple change of the adjustments it can be used for gasoline. For alcohol, however, the makers provide a special float, the carburetor remaining the same otherwise. It has two needle valves: one projecting downward from the top of the device A, called the slow-speed needle; and the other, projecting upward from the bottom B, called the high-speed needle. The primary air for both enters at C, passes around the exhaust heating pipe D, and enters from below. It rises around the lower needle and fuel passage into the chamber E, where the fuel is picked up and carried up into the main vaporizing chamber F. From here it passes up into the passage G, where additional air comes in from the air valve H, after passing the air throttle I. This dilutes the mixture and completes vaporization, and the mixture passes the main throttle J into the manifold, or engine.

The fuel enters the float chamber K, in which the float is indicated, and passes from this through the horizontal opening L to the needles. As there is hot air in the passage just below the opening, and exhaust gases in the passage just above it, it is subjected to a considerable warming effect. In the center at the bottom, a recess forms a dashpot for the lower end of the shaft M, which is connected to the air valve *H* at its upper end; this prevents rapid fluctuation, or fluttering, of this valve when there is a sudden opening of the throttle after running at slow speed. The extra suction created by the sudden opening of the throttle tends to jerk the auxiliary air valve open quickly to its maximum area. Another feature of the device is the feeding of small quantities of hot water from the motor circulating system through the pipe *N;* this has an adjustable valve (not shown) connected to the dash. The water is sprayed in through

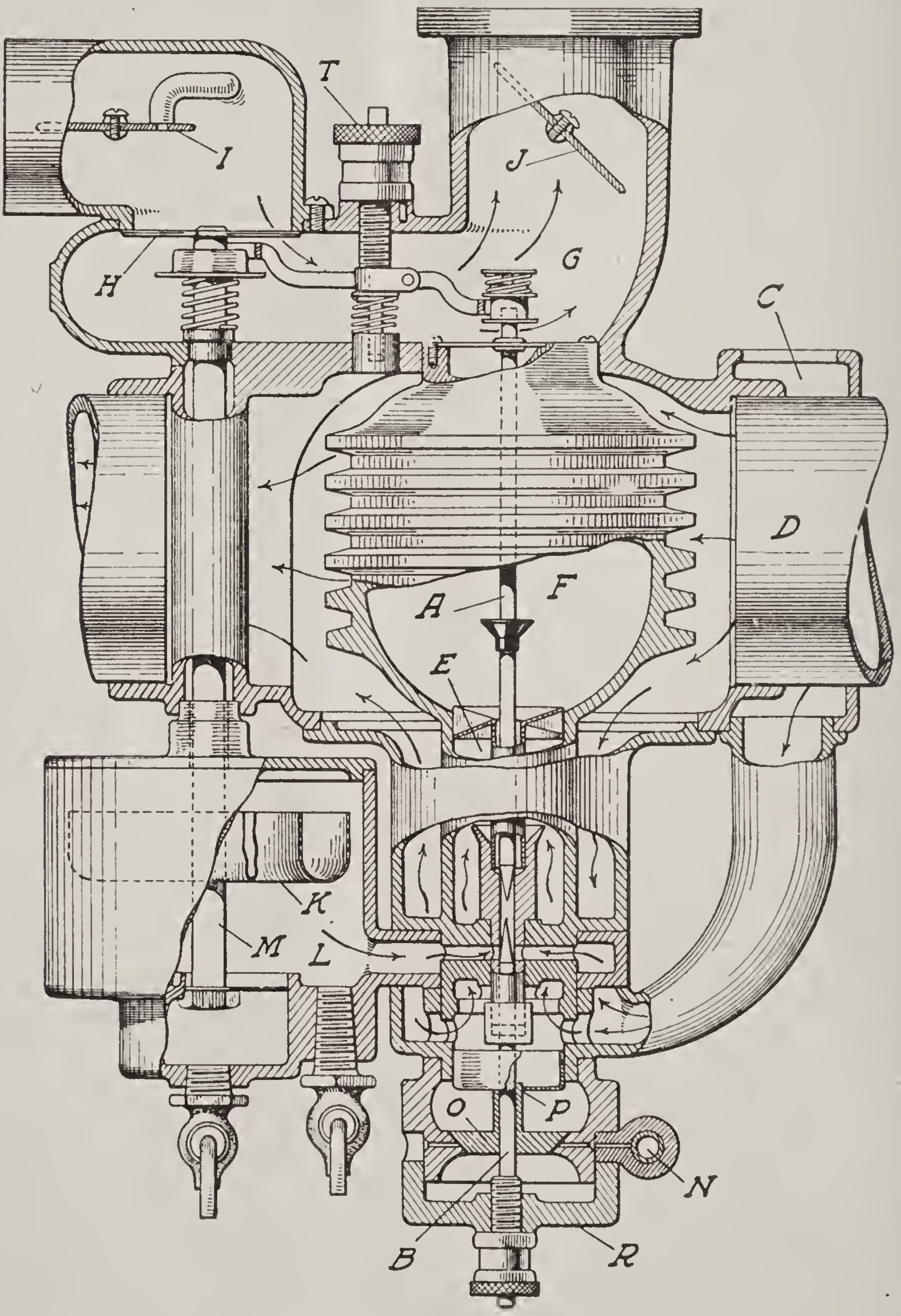


Fig. 128. Section through Bennett Double-Jet Kerosene Carburetor
Courtesy of Wilcox-Bennett Carburetor Company,
Minneapolis, Minnesota

the medium of the valve *O* attached to the bottom of the small dashpot and the plunger *P* which surrounds the bottom of the high-speed needle *B*. An additional feature of the device is an air cleaner *Q*, which is shown at the left in the diagram, Fig. 129. Its function is to clean all dust out of the entering air when the carburetor is used on a tractor or other unit which must work in the midst of considerable dust. As this dust is known to filter slowly but surely through the carburetor and, in time, reach the pistons, valves, rings, and bearings, where it does considerable damage, the utility of this simple auxiliary device, which has no moving parts, is evident.

Installation. Whenever it is possible to use the air cleaner, install the carburetor with the hood of the air intake facing away from the fan so as to prevent dirt from being blown into it. Connect the exhaust manifold to the carburetor, using the three-way valve or damper in such a way that the amount of gas can be regulated. Whenever possible the exhaust connection should enter the larger end, because the cored passage for heating the primary air is there. Screw an elbow in at the other end, and, if required, a short piece of pipe, to carry the used exhaust gases away from the carburetor. Connect the water jet near the bottom with the water jacket or a small auxiliary water tank. This water jet and its regulating needle can be moved to any desired position by means of the large nut *R*. The needle is connected to the dash so as to be operated by the driver. Two fuel tanks are needed, one for gasoline to be used for starting,

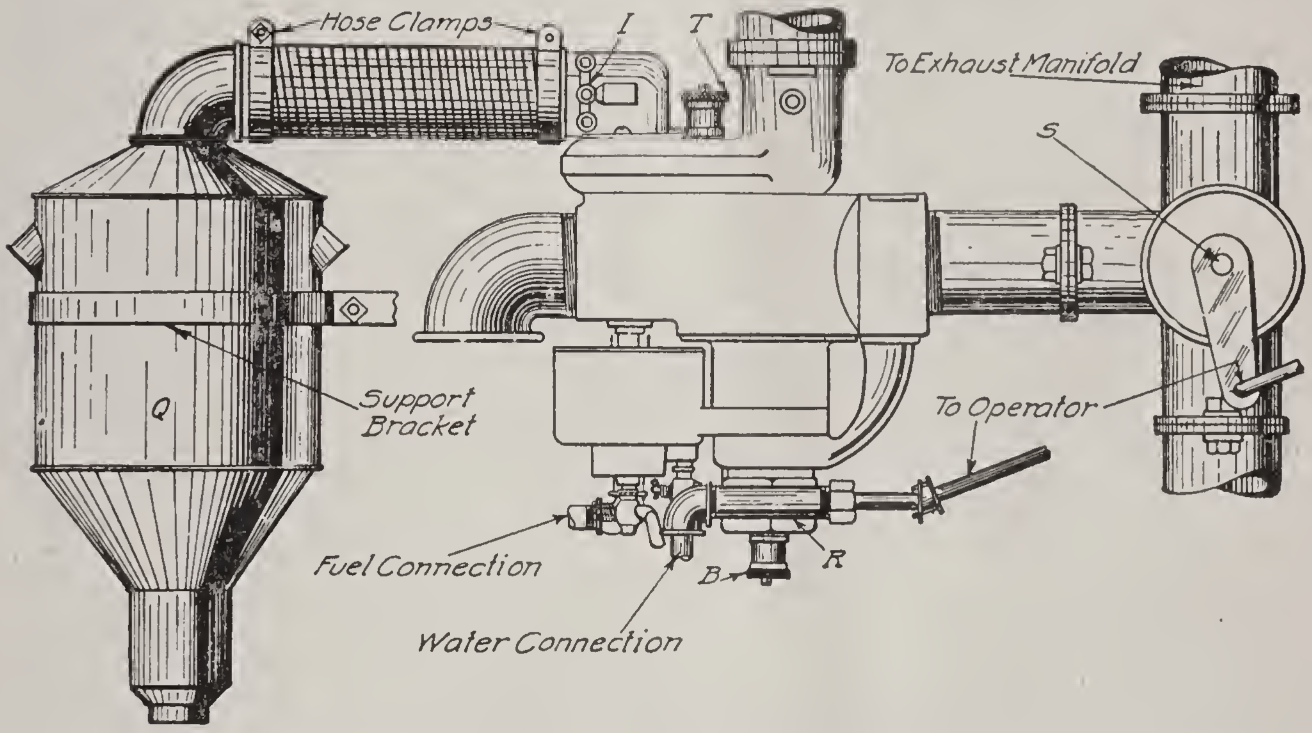


Fig. 129. Diagram Showing Method of Connecting and Adjusting Bennett Carburetor

and the other for kerosene to be used in regular running; they should be connected to the float chamber at the bottom by means of a three-way valve or a siamesed pipe, with a shut-off cock in each line above the **T**-connection.

Adjustment. There are but two adjustments, so-called: the high-speed fuel needle for full load; and the slow-speed fuel needle for slow speeds and idling. Both are made by knurled nuts, which are turned clockwise to close and counter-clockwise to open. In the process of adjusting, close the exhaust damper *S*, so as to throw the exhaust gases through the carburetor and furnish the needed heat. Then close the air-choke valve *I*, to make a rich mixture for starting purposes. Before turning on the gasoline, open the high-speed needle *B* about two turns. Then start the motor and immediately open the air choke valve *I*. If it fires unevenly after running a little while, close the slow-speed needle *A* by turning the knurled nut *T* to the right, one notch at a time, until the motor fires and runs evenly when throttled down to the slowest speed. If the motor hesitates and stops when the air choke valve is opened, open the slow-speed adjustment, one notch at a time, until the point is reached at which the motor will just run and fire evenly when throttled down.

Regulate the high-speed needle until the motor will respond when the throttle is opened quickly, by speeding it up to its maximum number of revolutions without missing. If the motor misses when the throttle is jerked open, close the needle slowly, one notch at a time, until the missing ceases and the motor responds to the quick opening smoothly. On the other hand, if the motor back-fires when the throttle is suddenly opened wide, open the needle slowly until it will speed up without missing or popping back. As soon as motor and carburetor have become thoroughly heated, turn on the kerosene and shut off the gasoline.

Kerosene Modified Adjustments. The use of the kerosene may change the adjustments slightly. Thus the slow-speed needle adjustment may have to be opened one or two notches more for kerosene than for gasoline. Similarly, the high-speed needle adjustment will have to be opened two or three notches more. If the motor becomes so hot when running on kerosene that pre-ignition occurs—and this is likely because the whole device is designed to use the maximum possible amount of heat—the water-needle connection to the operator should be opened. This pre-ignition can be detected as a sharp metallic knock in the cylinder. Only enough water should be used to stop the knock; the carburetor should not be flooded with it. The cap at the bottom, or inlet, of the air cleaner Q should be kept tight. The air cleaner should be emptied once a day, but it should not be removed while the engine is running.

Bennett Air Washer. The wider use of tractors and also of cars and trucks in the country, over dusty roads, and in the dust-laden fields which are being plowed, harrowed or otherwise worked, has forced the use of devices for removing the dust from the entering air. The device indicated at Q is one of these and is shown in detail in Fig. 130. Its interior consists of a series of spiral passages. The air enters one of these at A and is forced to pass through the water. Then it passes upward and out along the other spirals C, C. The air is doubly purified, first by passing through the water, second in the removal of dirt by centrifugal action.

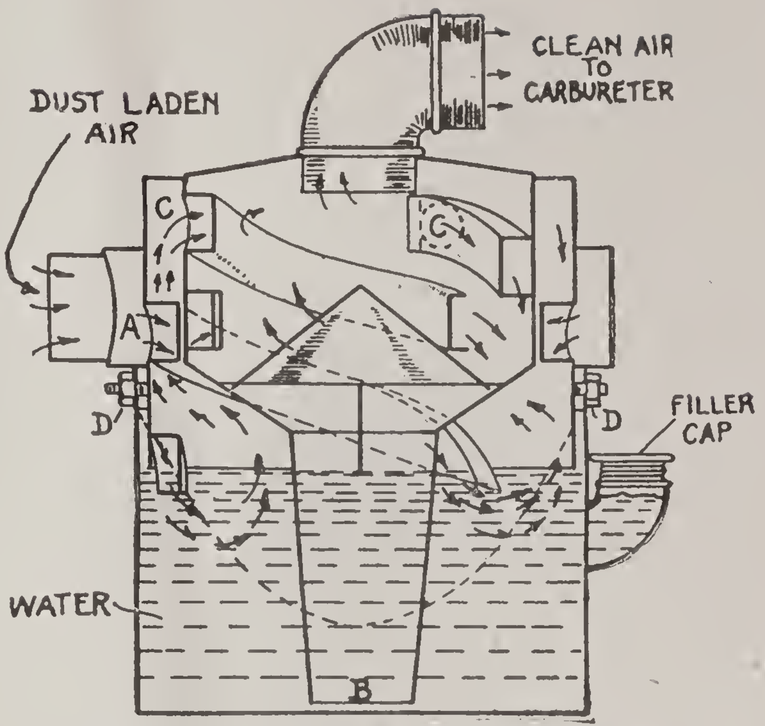


Fig. 130. Bennett Air Washer, Indicating Operation
Courtesy Wilcox-Bennett Company, Minneapolis, Minnesota

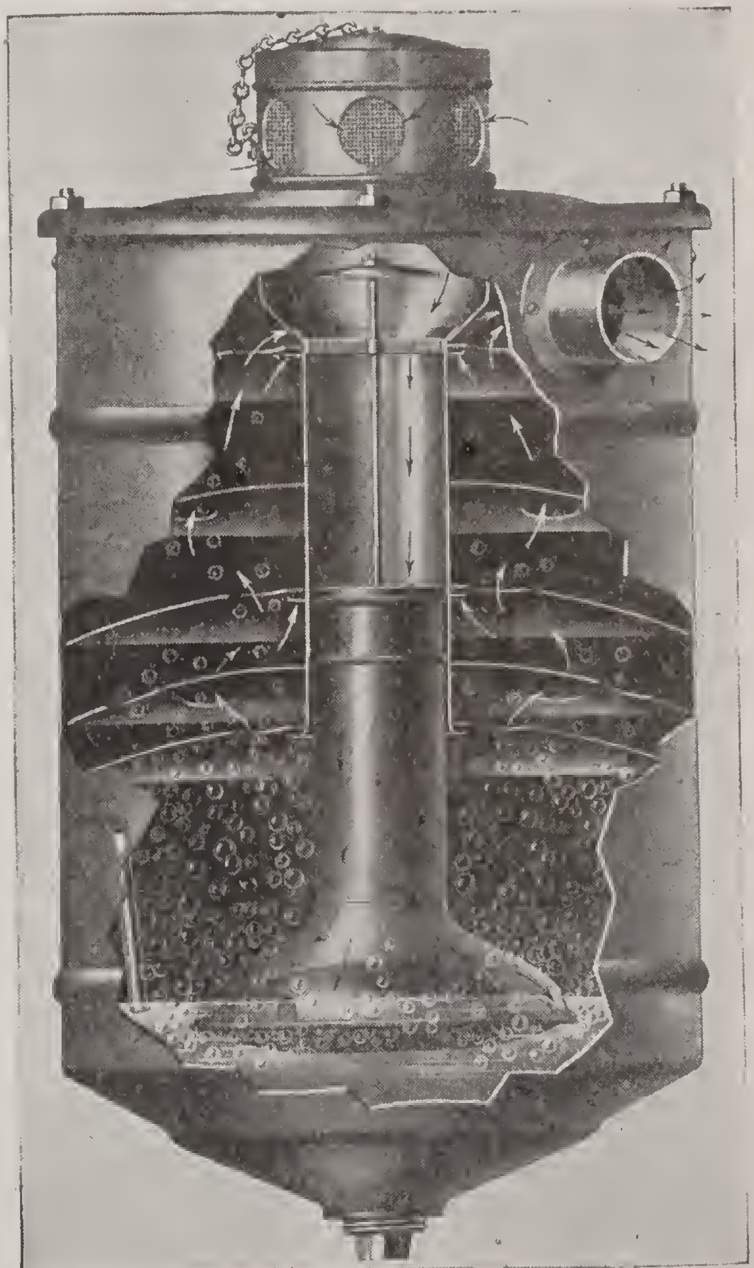


Fig. 131. Parrett Air Cleaner for Removing Dust and Dirt
Courtesy Ross-Wortham Company, Chicago

Parrett Air Cleaner. A similar device working on a different principle is the Parrett air cleaner shown in Fig. 131. Air enters at the top and is drawn downward through the central tube, the lower part of which is flared out and is supported on a metal float smaller than the bottom of the bell. The air passes between the two, through a very narrow opening, at high velocity. Large air bubbles can not form, and because of the high velocity all heavy dust particles are thrown directly into the water. The rising purified air and moisture are separated by a series of baffle plates so the air finally passing to the carburetor is completely cleaned of dirt or dust.

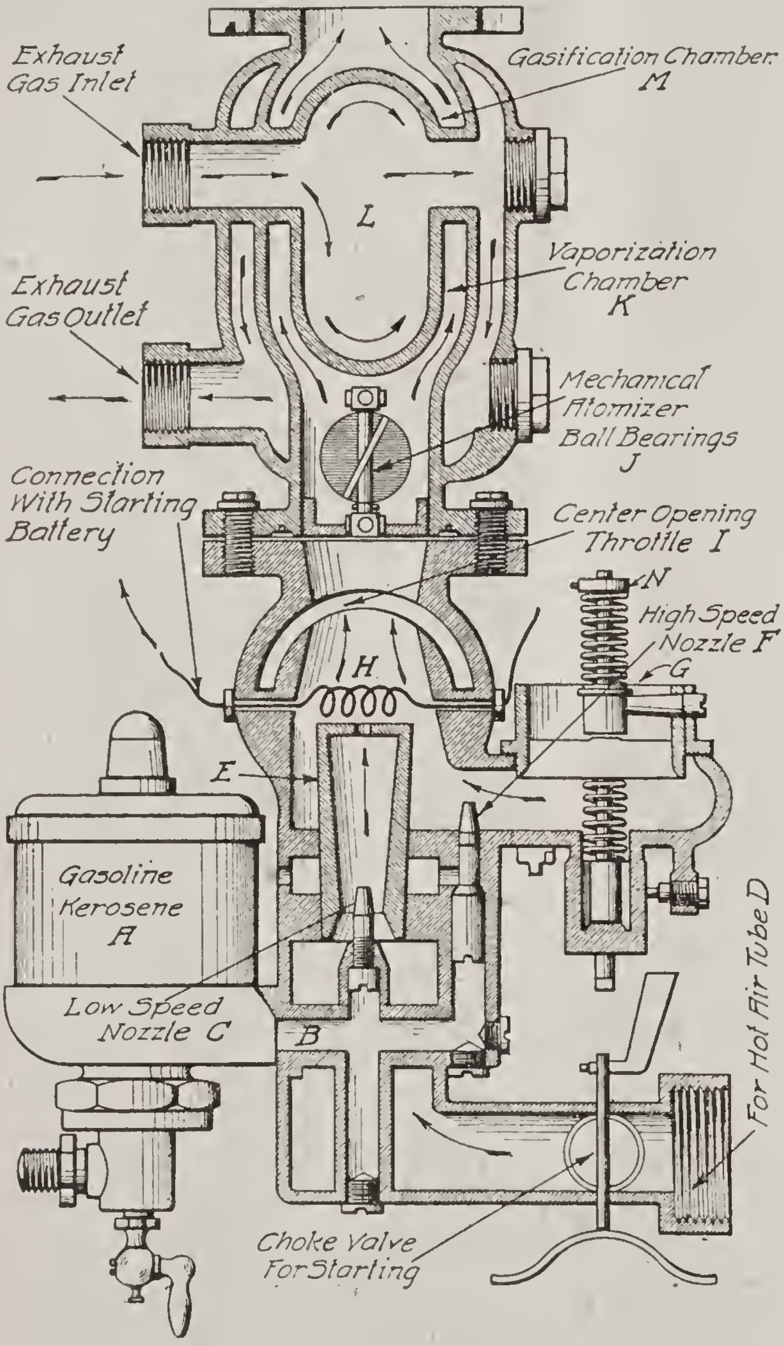


Fig. 132. Section of Deppé Gas Generator, Showing Construction
Courtesy of W. P. Deppé, New York City

Deppé Gas Generator. Although not called a carburetor by its maker, the Deppé gas generator replaces the ordinary carburetor for the purpose of vaporizing kerosene. In appearance and in sectional drawing, as shown in Fig. 132, it is not unlike an ordinary carburetor with an extra-special somewhat globular chamber above it, and below it the ordinary inlet manifold, which is exhaust heated. Some of the things claimed for it, when it is attached to ordinary cars with no change except in the vaporizer, are: perfect gas at all speeds; superior acceleration; no loading; increased high speed; lower slow speed on high gear; much greater fuel efficiency expressed in miles per gallon; handles all ordinary hydrocarbon liquids—gasoline, kerosene, naphtha, etc., and mixtures of these; fixed metering adjustment which is not affected by altitude, temperature, or location; easy starting; less vibration of engine; and others.

In Fig. 132, the fuel enters the float chamber *A* from below and passes through a horizontal passage *B* from which the two nozzles lead upward. The low-speed nozzle *C* draws its heated air through the primary intake *D* and mingles with this in the modified Venturi *E*. When the engine demands more fuel, it is supplied by the high-speed nozzle *F*, which gets its air from the auxiliary air valve *G;* this air and fuel mixture combine with the other in the chamber *H*, just above the Venturi and just below the center-opening throttle *I*. Up to this point it is not radically different from the average two-jet carburetor with the auxiliary air valve.

However, in the chamber just above this a mechanical atomizer, or rotating mixer on ball bearings *J*, is inserted. The idea is to combine the air and fuel particles more intimately through the rotation of this mixer within the zone of vaporization. The actual vaporizing chamber *K* is next above this. It is an annular passage around the highly heated exhaust gas chamber *L*, but inside of the outer exhaust chamber. This insures the absolute completion of the gasification started in other chambers, so that the mixture passing into the gasification chamber *M* at the top and thence into the inlet manifolds and cylinders is sure to be a pure dry gas.

Starting. To assist in starting, the primary-air passage is fitted with a choke valve of the butterfly type, which closes off this passage entirely so as to produce a rich mixture. Across the middle of the lower vaporizing chamber *H*, an electric resistance wire or heating coil is strung. The coil is connected to the starting battery. The connection is made so that the current passes through this heating coil as soon as it is turned on. This supplies the cold carburetor with the equivalent of the exhaust gas heat, which is available shortly after the engine has been started.

Adjustments. As will be seen from the illustration, the low-speed nozzle and air opening are fixed, the only possible adjustment, setting, or change being in the alteration of the nozzle or in the quantity of primary air admitted. The high-speed nozzle is fixed similarly so that it cannot be adjusted, the high-speed air valve *G* furnishing the only adjustment. The adjustment of this is very simple;

with the engine running, advance the spark pretty well to the limit, open the throttle lever to its maximum, and then vary the position of the nut *N* which governs the tension of the spring *O* to the point where the maximum speed of rotation is obtained. This setting should be checked against actual high-speed running on the road, as there is usually a difference between the best road high-speed setting and the best engine-speed setting, with the car standing on the garage floor.

Ensign Heavy Fuel Carburetors. A section through a new device recently perfected on the Pacific Coast, the Ensign carburetor, is shown in Fig. 132 A, while Fig. 132 B is a horizontal section of the vortex mixing chamber which forms an important part of this. This device was designed to handle heavy fuels, but that shown in Fig. 132 A can be used for gasoline. As the figure shows the fuel enters a float chamber, thence into the bottom of a standpipe *H*, within which a suction tube *A* is set with its top opening slightly above the fuel level so that fuel must be drawn up by the air suction. This air enters at *B* and passing around the vortex, of which Fig. 132 B shows a better view, acquires a high velocity. Thus a considerable suction is exerted on the fuel which passes out through holes *D* into the whirling air stream, which vaporizes it. Should any fuel moisture remain the centrifugal action of the air stream throws it against the walls whence it drips down through holes *J* into the mixture which passes through the narrowed throat *K*, thence makes a sharp bend to a horizontal direction, and another to a vertical flow entering the inlet pipe *V* on its way past the throttle *M* to the cylinders. The nature of this vortex chamber thins the mixture as it is produced at *D*, and with increasing demands, and thus increasing air velocity, continues to thin it, so the vortex chamber automatically delivers a thinner and thinner mixture as the engine speeds up.

Adjusting the Ensign Type G. This model has two adjustments, air at *A* and fuel at *G*. Screw both of these clockwise to a closed position; then open *G* one and a half turns, and *A* one-fourth turn for four-cylinder motors, one-eighth turn for six or more cylinders. Start the motor and warm it up. Open the throttle to high speed and use *G* as a needle valve, adjusting to get the highest motor speed. Then refine this by adjusting *A*, one notch at a time. To start cold, open throttle *M* to slightly more than an idling position, and pull primer *Y* heavily before cranking.

Ensign Fuel Converter. This company's Model "N" device is intended to handle the very heaviest fuels, up to a dry boiling point of 600° F. It consists of three elements, the carburetor proper, the gas producer and the temperature regulator. Fig. 132 C shows that the first is almost identical with the carburetor shown in Fig. 132 A. To this is added the gas producer which consists of the fire screen *U* to which the heavy unvaporized fuel flows, the combustion chamber *Q* and the sparking element *A* which ignites it. This heats up screen *U* and the plate *C* below it so that these subsequently vaporize a larger portion of the fuel, and less of it passes down into chamber *Q* to be ignited and thus vaporized. That is, this part of the device is self-regulating as to temperature. The idling temperature is controlled by thermostat capsule *N*, operating temperature control plug *M*. This is half full of alcohol, and its chamber is provided with means for circulating the hot mixture. As the mixture approaches 210° F. the capsule pushes the plug outward and closes the port *O* reducing the draft and thus controlling the temperature.

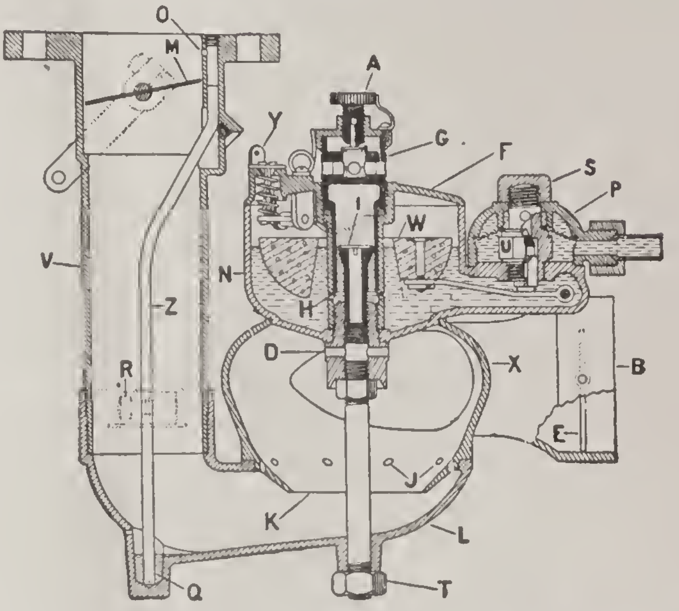


Fig. 132 A. Ensign Carburetor, Model "G"
Courtesy Ensign Carburetor Company, Los Angeles, California

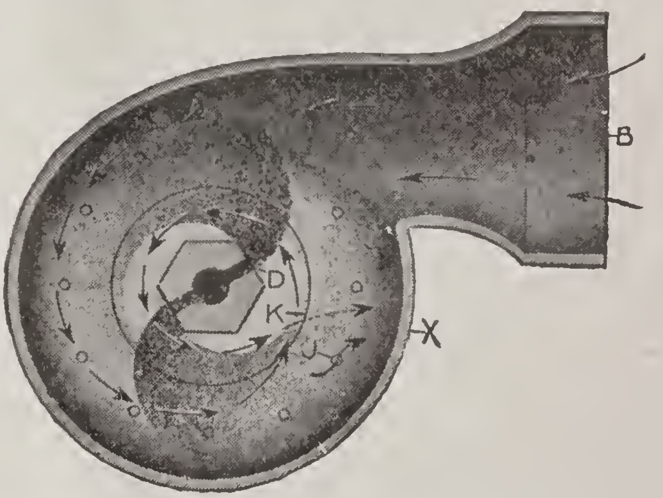


Fig. 132 B. Horizontal Section of Ensign Carburetor Showing Vortex Mixing Chamber

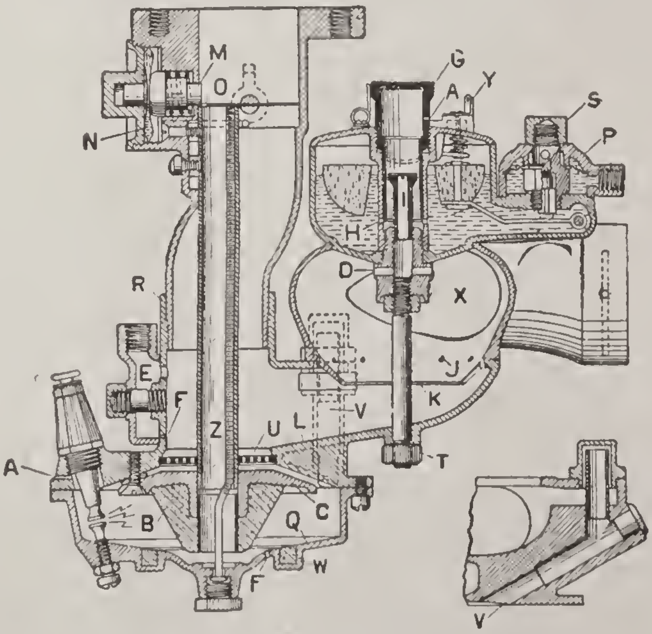


Fig. 132 C. Section through Ensign Fuel Converter

Adjustment of Ensign Fuel Converter. Adjustment of this device is the same as the carburetor previously described, except for starting and with the addition of the spark plug care. In starting *G* is opened 1 turn, then *E* is filled with gasoline to fill the fire bowl up to the overflow *F*. If motor and converter are hot, prime very little; if motor has stopped but a few minutes, prime with *Y* on top of the flat bowl and start directly on the heavy fuel. With spark retarded adjust *G* to maximum engine speed. After engine has been running some time check this adjustment.

CARBURETOR TROUBLES AND REMEDIES

Engine Should Start on the First Turn. In starting a car cr any engine, whether located in a car or not, everything should be inspected so as to know if all is right before attempting a start. With the novice, this is somewhat of a task, but to the old hand it is so much of a routine task that he does it unconsciously. If all conditions are right, the carburetor is primed and the engine will start on the first turn of the crank. If it does not do so, there is a source of trouble which must be remedied first, and it is useless to continue cranking. The trouble may lie in the fuel system itself, but exterior to the vaporizer, or it may be in the ignition apparatus. It is well in a case of this sort to start with the gasoline tank and follow the fuel through each step until it apparently reaches the combustion chamber in the form of a properly proportioned mixture of gasoline and air.

To start with the tank—is there enough fuel in it not only for starting purposes, but enough to allow of making the proposed trip? This is readily ascertained by unscrewing the filler cap and inserting a measuring stick. For the purpose a graduated rule is good, but not necessary; any stick or small branch of a tree will answer, or, lacking all these, a piece of wire can be used.

Having verified the presence of fuel, the next question is: Does it reach the vaporizer as it should? Nearly all carburetors have a drain cock at the lowest point. Open this, and if fuel flows out in a steady stream, you may be sure that the pipe from the tank up to this point is not clogged.

In either case, if there is no sign of gasoline when the tank contains plenty, it is apparent that the feed pipe is clogged. To remedy this, the method of procedure is as follows: Shut off the cock below the tank so that none of the previous liquid can escape, then drain off the carburetor and pipe into a handy pail. Next, open the union below the cock in the feed line and the one at the other end of the same pipe. At both places look for obstruction. Then clean the pipe out thoroughly, using flowing water, a piece of wire, or other means which are available at the time.

Gasoline Strainer a Source of Trouble. If you find nothing here, look in the strainer of the carburetor to make sure that the flow is not stopped there by the accumulation of dirt and grit, filtered out of the fuel. The strainer should be cleaned often, but, like many other dirty jobs, it is postponed from time to time.

Should this source of trouble prove "not guilty" the carburetor itself becomes an object of suspicion. Is the float jammed down upon its seat, or are there obstructions which prevent the flow of fluid? Is the float punctured, or has one of the soldered joints, if a metal one, opened, or is it fuel-soaked, if cork?

Bent Needle Valve=Stem. To attend to this sort of trouble, disconnect the priming arrangement, take the cover off the float chamber (it usually is screwed on with a right-hand thread) and take the float out. An examination of the float, Fig. 133, will disclose whether it is at fault in any of the above-mentioned ways, all of which are comparatively easy to fix. If the float was jammed down, perhaps by priming, the act of taking it out will loosen it, provided that the stem of the float is not bent, and the needle valve or its seat is not injured. If the seat is scored, it should be ground-in just like any other valve, using oil and fine emery. A fuel-soaked cork should be thrown away if another is at hand to replace it, but if not, the cork float should be moved in its position on the stem so that it sets higher in the liquid. In other words, move the cork up sufficiently to compensate for its loss of buoyancy.

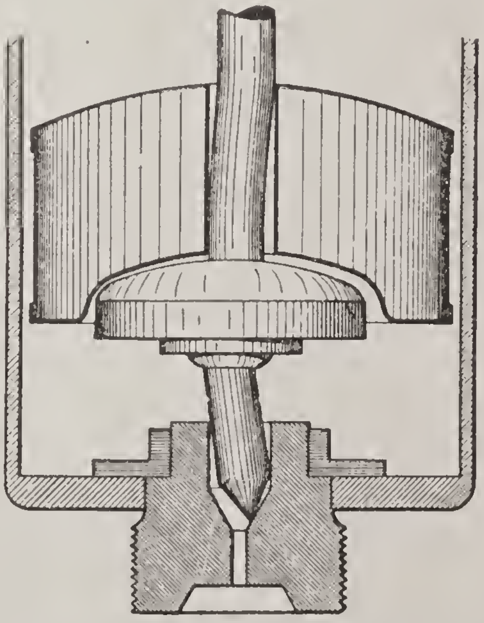


Fig. 133. Bent Needle Valve

In case of a punctured metal float or of loose solder, the only real remedy in either case is to resolder. It usually happens that a soldering outfit is not available out on the road, and some form of makeshift will be necessary in order to reach a place where one may be had. If the puncture is on the bottom, it is sometimes possible to accomplish this by inverting the float so that the hole comes at the top where the gasoline seldom reaches it. If the flow be reduced to make sure that the float will not fill up, it is possible to reach a place where a soldering iron may be procured.

A remedy which might be tried in an extreme case of this sort is to fill the float to make it heavy, so that it will have a tendency tc sink. Then take a spring of small diameter, cut off a short piece and place it in the float chamber so that it opposes the sinking action of the now heavy float. By carefully determining the length and the strength of this spring, the same action is obtained as if the float were working all right. If the entrance of the liquid fuel is such that the sinking of the heavy float tends to close rather than open the gasoline inlet, the spring would have to be on the bottom and fairly strong so as to oppose the action of gravity. But if the float works downward to open the gasoline passage, the spring will be at the bottom and very weak being there simply to prevent an excessive flow.

Throttle Loose on Shaft. Now the carburetor trouble has been reduced to a minimum. The remaining troubles might be centered in a clogged spraying nozzle. But this nozzle is readily removed, and with it the trouble, if that be the offending member. If the spray is proven O. K., the throttle is ready for attention. If of the butterfly type, it may have become loose on its shaft, or, what is the same thing, the operating lever may be loose. In either case the shape and weight are such that it would swing into such a position as to cut off the entrance of gas to the inlet pipe and thus to the cylinder. If the throttle is of the circular sliding or piston form, it may not be connected to the throttle rod, but is stuck in such a position as to prevent the passage of gas. This sometimes happens when running, and then, apparently, closing the throttle does not stop the engine. The writer had this happen to him once at a time when it was absolutely necessary to stop. The only way that trouble was averted was by the instantaneous closing of the switch and the hasty application of the brakes.

The last hope of finding trouble in the carburetor system rests with the inlet pipe. If the source of the trouble is not found elsewhere, take this off in search of misplaced waste or similar substances. The size of the pipe is such that anything in it large enough to cause trouble may be instantly seen and removed. The only exception to this is a small hole in the inlet-pipe casting, which, if clogged even with a grain of sand or other material, will not only cause trouble with the mixture at all times, but will also be very hard to find, particularly if it happens to be of very small diameter.

The valve, or cock, controlling the flow of liquid from the tank should be examined frequently and care be taken to keep it in good shape. It must act hard and must be tight, so that no gasoline flows when it is supposed to be shut off. If this valve does not act hard it is likely to jiggle shut during a long run and stop the engine by shutting off the gas supply from the tank. A method of fixing it—which, in general, is not to be recommended—is to open the cock and then hammer the handle so as to jam it tight against the seat, but in the open position. This makeshift will answer until a place is reached where the taper seat can be reground or tightened in place, if that is what it needs. In case the driver does not wish to do this, and the cock is of the two-way type—open when the handle is parallel to the axis of the pipe—it may be tied in the open position by passing a cord around the cock and pipe.

Carburetor Adjustment. In adjusting the carburetor the worker should remember that the correct proportion varies from 11 to 14 parts of air to 1 of gasoline vapor. It is not always possible to measure the two in just this way, but the adjustment is provided for in the carburetor. The tendency in carburetor construction is toward simplification and fewer adjustments. In making carburetor adjustments, always remember to make them with the motor hot. A good plan is not to make any adjustments of this kind until after the motor has been running for an hour.

Tool for Carburetor Nozzles. Many carburetor nozzles are made with a screwdriver slot to facilitate their removal. It will soon be found, however, that the screwdriver is not so easy to use on these as a home-made tool. One useful form consists of a bar of $\frac{1}{4}$-inch steel-bar stock bent into the form of an L, the short end being flattened down into a screwdriver thickness and hardened.

Starving at High Speeds. Many times, a motorist will experience the phenomenon known as starving at high speeds, that is, his motor will give better power and run faster with the throttle partly closed than when wide open. This happens when the auxiliary air valve does not open sufficiently to admit the large quantity of air needed at the widest throttle opening. The mixture, therefore, becomes too rich, and the motor starves. The auxiliary air valve usually has an outside spring, the tension of which is controlled by a milled nut, also on the outside. Then, when it is desired to make a change in the mixture, the nut is turned, altering the tension of the spring and thus altering the lift of the air valve; in this way the proper amount of air is admitted. To admit more air, the nut is backed off in order to weaken the tension and thus allow the air valve to open wider. To admit less air, the spring tension must be increased so that the air valve cannot open quite so far or stay open so long.

Adjustments for Heating Water and Air Supply. On a large number of carburetors there are two more adjustments: those for heating the water and those for heating the air. The general run of carburetors are now water-jacketed to help vaporize the heavy fuels; during warm weather this may supply too much heat. For this reason, a cock is generally fitted to the hot-water line, which will allow partial as well as total closure.

Similarly, hot air is supplied to almost all carburetors to vaporize the heavy fuels more quickly, a necessity if rapid acceleration, quick getaways, and other present-day demands are satisfied. In order to vary the hot air according to the weather or to cut it off entirely, some kind of a shutter is provided which can be locked in any position. When the days begin to grow warm late in the spring, the shutter is partly closed; during the heat of mid-summer, it is closed completely, and sometimes the connection with the exhaust manifold for heating the air is entirely removed from the car; when the temperatures begin to go down, the shutter is opened again, and in cold weather it is entirely open, and as much heat as possible is supplied the carburetor.

Adjustment of the Nozzle. *Nozzle Too Low.* A rather common trouble is failure to start readily. One puzzled driver described his case as follows:

> The engine starts hard, necessitates priming, and the primer must be held down for a long time. When this is done, it will start and run for a short distance, when it will stop and the same proceeding must be repeated. On taking the carburetor apart, everything was clean and apparently all right.

If you are ever bothered in this way, you may be sure, granting that the spark is good, that the trouble lies in the fuel system. From the description of the trouble, it appears as if conditions were such as to starve the engine, although this was doubtless done unconsciously. This action is due to the fact that the gasoline level has been lowered so far that the suction of the engine does not draw up sufficient fuel for running. The fact that you have to prime to start and then prime to keep going, even this priming failing to work sometimes, would seem to prove that the engine is not getting enough fuel. The trouble is that the spray nozzle has been raised too high, so that the gasoline level is four or five times as far below the nozzle as it should be. The engine suction must raise the gasoline this distance before any of the fuel will get into the cylinder, and if the distance exceeds the height to which the suction can raise the fuel, none will pass over. In a case of this sort, priming only helps temporarily.

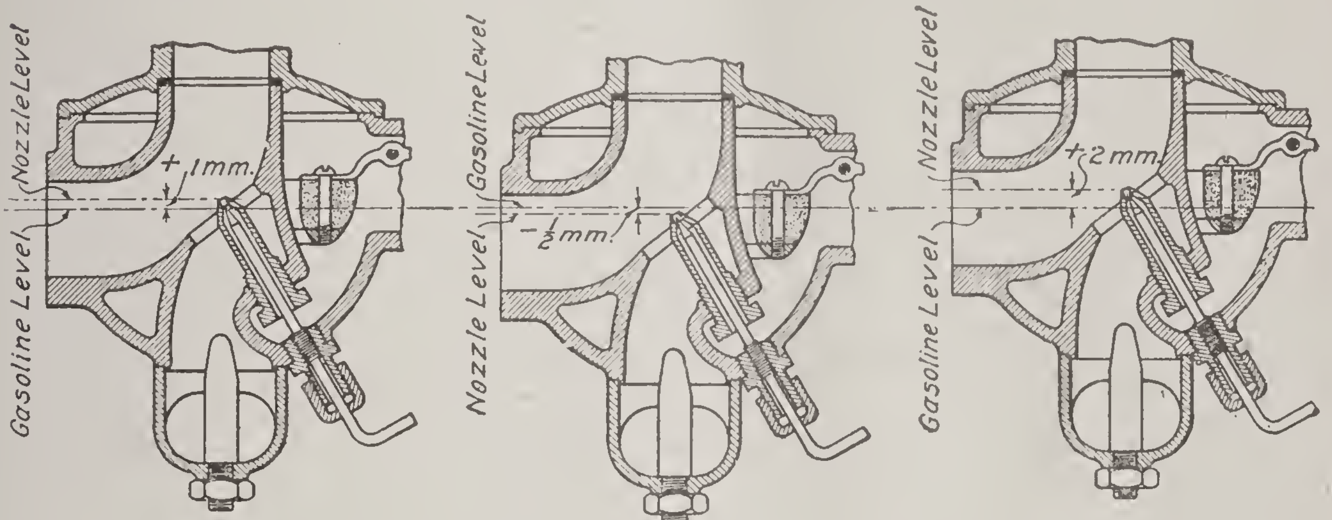


Fig. 134. Section of Carburetor Showing Variation of Nozzle Level. First Figure, Correct; Second, Too Low—Engine Will Flood; Third, Too High—Engine Will Starve

Wrong Adjustment of Jet Nozzle. The wrong location of the jet nozzle results when the fuel level, as fixed by the float, is not high enough to give the proper flow of fluel into the vaporizing chamber. Drivers who have trouble with this are frequently puzzled by it, because they assume that the carburetor is properly adjusted before leaving the factory. This is not always the case. One young driver said:

> What is the cause of this very puzzling knock? My four-cylinder engine develops a bad knock on a hill, which can only be eliminated by retarding the spark, but when that is done, the engine "dies", that is, gives no power. The effect is the same on level roads when the throttle is opened more than one third. I may have deranged the level of the gasoline within the carburetor while cleaning it. Would that have this result?

Now, this trouble is directly traceable to the change in the level of the nozzle made when cleaning and is made unconsciously. To quote from a plain statement of the effect of this change:

> By raising the spray nozzle, you lower the level of the gasoline relatively. Therefore, the liquid is less sensitive to the suction, which would reduce the amount of gasoline used. At low speeds, there would be a tendency to *starve the engine, which would be most noticeable on hills.*

The trouble is that the spray nozzle has been raised so that the engine does not get enough fuel at slow speeds and on hills. By lowering this a small amount, Fig. 134, the engine will be able to suck up more fuel and the trouble ceases with the change. In making this change, be careful not to lower the nozzle too much at once, as the effect then is just as bad, the carburetor flooding at the slightest provocation. The better way is to lower the nozzle a very slight amount, say one-quarter of a millimeter, or perhaps one sixty-fourth inch would not be too much. Try this level out very thoroughly, and when you are satisfied that it is not right, alter the level once more. The experience that you will get during the process will be worth all the time taken up in the series of successive adjustments.

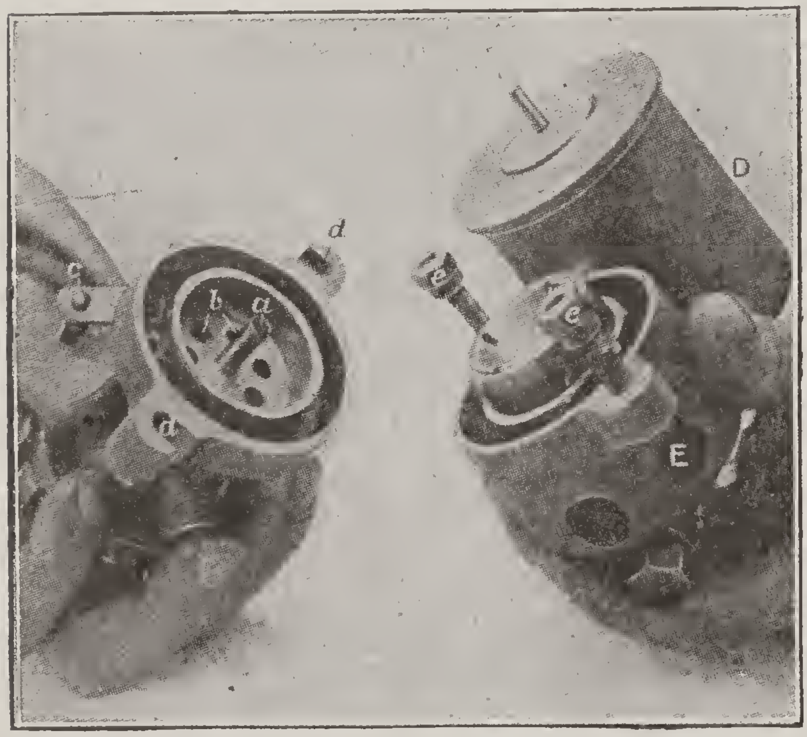


Fig. 135. Method of Dismantling a Carburetor

Cleaning the Carburetor. Cleaning the carburetor, then, should be done very carefully, until one becomes quite familiar with it and with the influence which movement of the various parts will have. In Fig. 135, a foreign carburetor partly taken down shows how the top part of the float chamber should be removed in order not to damage the delicate needle point at the bottom of the float by which the latter governs the fuel supply. The cover should be loosened and then lifted straight up until clear of all remaining parts. With the cover off, the float may readily be removed in the same way, the only care being in starting it. As the amount, or length, of the needle point within the tapered seat is small, the float need be raised but a small amount to clear that. Then, it may be lifted out as one desires, since it usually is made from a half inch to an inch smaller in diameter than the chamber within which it works.

Smallest Detail Important. The influence of the smallest things may be of great importance, as illustrated in Fig. 136. A man having a small runabout with a rather large air vent in the gasoline tank, which was located directly over the engine, was bothered, in climbing hills, by too rich mixtures. These not only caused the engine to smoke badly, but caused a lack of power. On investigation, he found that the carburetor was located below and nearly underneath the gasoline tank. On a hill, the gasoline flowed out of the air vent, down the side of the tank, and dropped into the air intake, thus increasing the mixture. Obviously the cure for this was to change the air intake so that the overflow from the tank could not drop into it or into any part of the carburetor. The sketch, Fig. 136, shows how he was advised to change it; the comment on the trouble and the proposed change were as follows:

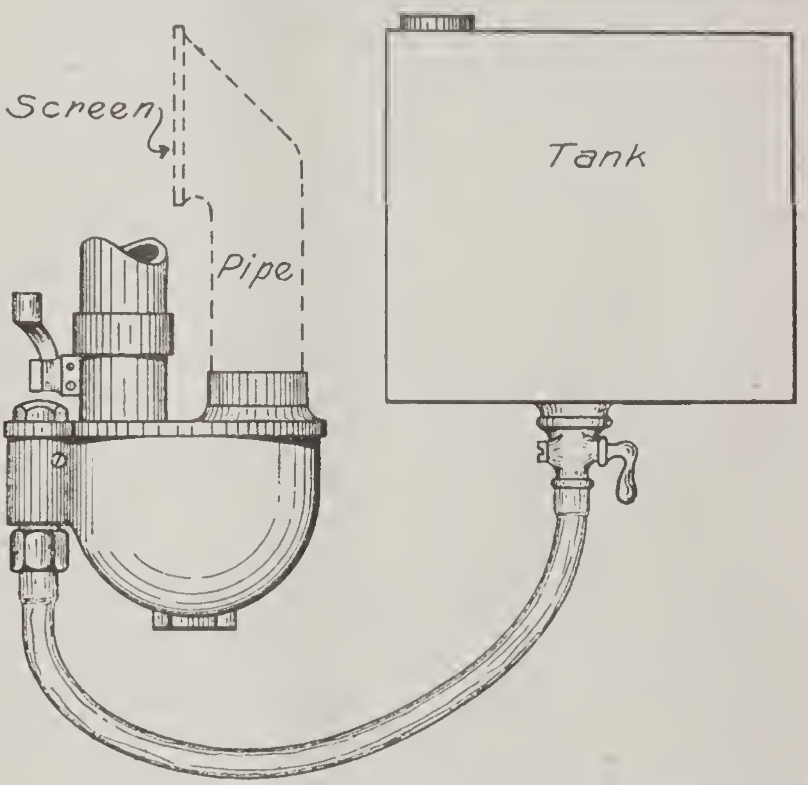


Fig. 136. Puzzling Carburetor Problem Solved

The addition of fuel, as you describe, to the air at the air inlet will seriously disturb the running of the engine and probably give so rich a mixture as to choke the engine. It is advisable to remedy this at once, and the best way to do so is to prolong the present air inlet upward and outward away from the gasoline tank which causes the trouble. To do this, have a sort of stove pipe made of galvanized iron, tin, or any similar metal. It should be long enough so that its top is as high as the top of the offending tank, then make a big, easy bend away from the latter. The opening, or mouth, of the pipe should be so formed as to take a screen, which is necessary to keep out the dust and should preferably be made removable, so that when the screen clogs with dust it can be taken off, cleaned, and replaced. For this purpose use a very fine brass gauze, which can be obtained at any hardware store at small cost.

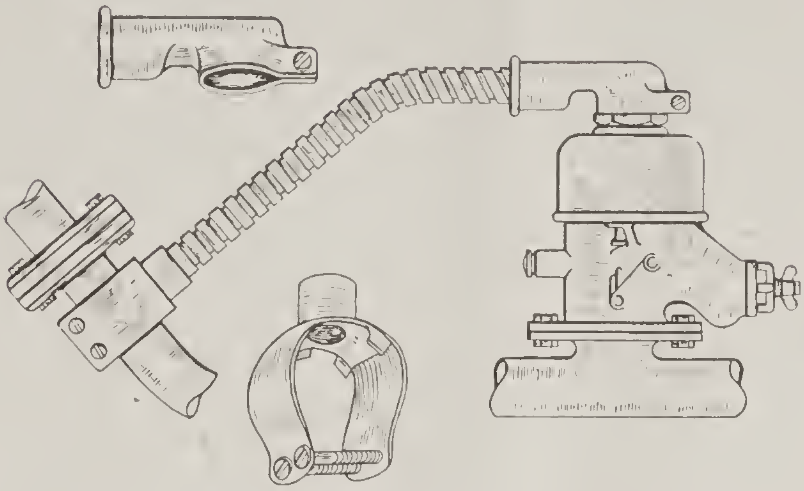


Fig. 137. Method of Adding a Hot-Air Connection to Improve Carburetion

Pre-Heating the Air. One thing that gives a lot of trouble is the heavier fuel now supplied. It can be used successfully only by adding heat, the application of which may take one of two forms: a water or exhaust-gas jacket around the carburetor, or an arrangement pre-heating the air supply. The former cannot be added, but the latter can very easily. This is done, as shown in Fig. 137, by running to the air inlet for the carburetor a flexible metal pipe from a collector fastened to the exhaust manifold. This tubing can be obtained at any well-equipped automobile supply house, as can also the various fittings for the exhaust pipes. In some cases, these firms carry the carburetor hot-air attachments also, but, if not, the maker of the carburetor can supply them at low prices. By the use of this attachment, the air drawn in through the carburetor passes around the very hot exhaust pipe, hence it is heated a great deal.

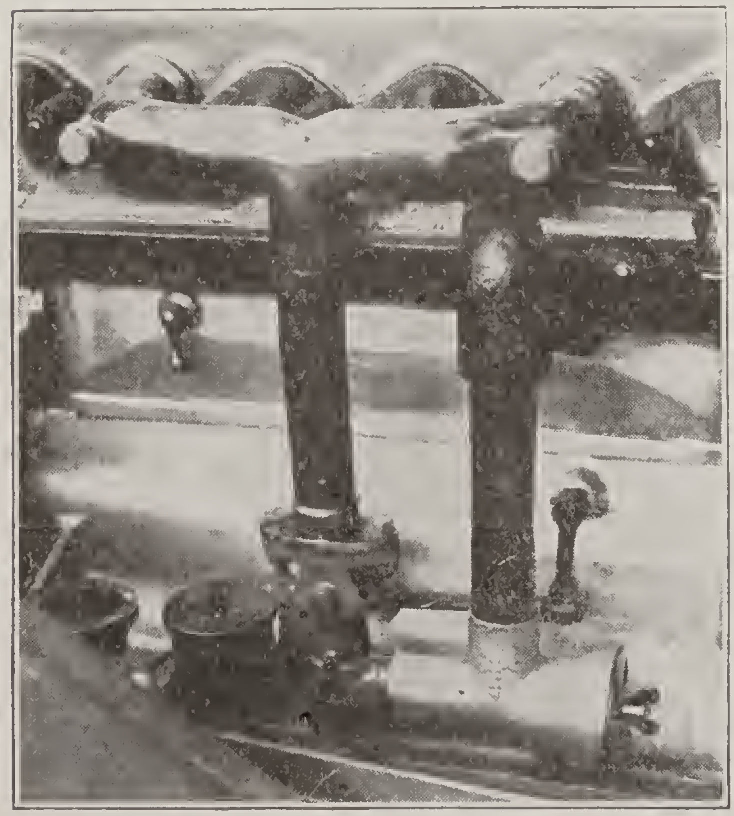


Fig. 138. Hot-Air Pipe to Carburetor on Belsize (English) Car

Practically all late-model cars are equipped with a carburetor having a hot-water jacket and a special pipe for leading heated air to the carburetor. In Fig. 138 is an English example of this, showing the carburetor connections on the four-cylinder Belsize. The pipe at the left is the inlet manifold and the one at the right, the hot-air pipe from exhaust manifold down to air inlet. In all cases this hot-air connection is made as short as possible.

Causes of Misfiring. There are a number of vexatious things to make the novice and prospective driver peevish. Chief among these is the trouble known as misfiring. This may be described as a failure of the mixture to fire in any one cylinder. It is usually due to ignition, so that the term, as used now, means a failure to fire a charge due to an electrical cause. However, there are many common misfires which are due equally as much to a failure in the fuel-supply system, so that the latter meaning attached to the word is a misnomer.

Among the causes which contribute to misfiring may be mentioned ignition troubles, such as short-circuit in wires, exhausted battery, pitted or improperly adjusted vibrators of the coil, sooty or cracked plugs, loose connections or switch, dirty timer or commutator, punctured condenser, moisture in coil, wet wires or cables, water on distributing plate, dirt or wear on contacts in distributor, or dirt or wear in timer.

Then, there are the misfires due in part or wholly to the fuel or carburetion system. These may be grouped or listed as follows:

Carburetion and Fuel. Faulty mixture, sediment, or water in the carburetor, clogged gasoline strainer, leaky float, clogged spraying nozzle, bent float-valve spindle, stale gasoline, partial stoppage of fuel-supply pipe, hole or obstruction in intake pipe or manifold—these are not all the things that might happen, but are the principal ones which the writer's experience has suggested as most likely to occur to cars in general.

Foremost among the several difficulties which may be called common misfires is the lack of a proper mixture. A rich mixture containing a relatively large proportion of gasoline in proportion to air is never desirable, inasmuch as it deposits considerable soot upon the piston, cylinder walls, and valves, and is, moreover, a waste of fuel. The motor will seldom run well on a very rich mixture, and the carburetor should be so adjusted that no more gasoline is fed to the mixing chamber than is sufficient for the motor to develop its full power. The exact mixture may be found by experiment.

A very rich mixture will cause misfiring; the motor will have a tendency to choke at other than high speeds and is likely to overheat. A lean or too thin mixture will, on the other hand, lower the efficiency of the motor, giving it a marked tendency to miss at high speeds, and is also accompanied by a popping sound in the carburetor. In this case, the needle valve should be adjusted to admit more gasoline, or, if due to an excessive supply of air, the auxiliary air valve should be adjusted to admit less air.

Bent Float Spindle. A bent float spindle will cause missing in one or more cylinders. The float spindle may become bent or it may become jammed into its seat by too vigorous priming. This may be discovered by unscrewing the cover and lifting out the float. Considerable care should be taken in straightening out a bent spindle, and the metal should be placed upon a block of hard wood, another block interposed, and the spindle gently tapped with a hammer.

Leaky Float. A leaking metal float or a fuel-logged cork will cause missing, owing to its uncertain and erratic action. A cork float should be thoroughly dried out and then given a couple of coats of shellac to prevent it from absorbing the gasoline. As a new float is not at all expensive, the driver will probably find it more convenient to put in a new one. A metal float must be soldered when it leaks. As the copper is thin and easily damaged, only a very little solder need be used. Precaution should be taken to keep the hot soldering bit away from the metal.

A clogged gasoline strainer is often the cause of trouble, and this is about the first thing that the autoist should examine when the misfiring is apparently in the fuel-supply system. The brass gauze strainer should be frequently taken out and cleaned of any dirt that may have been filtered out of the gasoline.

Obstructed Spraying Nozzle. Owing to the small needle-like opening in the spraying jet, it is not uncommon for a particle of grit to lodge in the orifice and partially stop the flow of gasoline. The obstruction will not always interfere with starting, but as soon as the motor speeds up, the amount of gasoline sucked through the nozzle will not be sufficient for the motor at higher speeds, and it will soon begin to misfire until the motor slows down to first speed. A leak in the intake manifold will cause misfiring and is often mistaken for ignition trouble. The cause may be due to loosening up of the bolts.

Summary of Gasoline System Troubles

Carburetors should be among the last things to change in case of trouble. A black smoke from the exhaust will indicate too rich a mixture. Too thin a mixture may cause back-firing through the carburetor.

Flooding of Carburetor. This may be due to the failure of the needle valve to seat properly, which may be corrected by grinding the valve; or to a punctured float which must be removed and the hole carefully soldered. It may also be due to the spraying nozzle being so adjusted that the opening is below the gasoline level. To remedy, raise the nozzle by easy steps until the correct level is obtained.

Filling of Gasoline Tank. This should never be done by lamp or lantern light.

Leaks in Gasoline Line. These must be repaired as soon as discovered. They may result in fire, destroying the car and endangering the lives of its occupants.

Filler Cap. The filler cap should uncover an opening in which is a strainer of gauze wire which should not be taken out, or, if broken, it should be replaced promptly. As an additional protection against small foreign particles getting into the gasoline system a funnel with a chamois skin through which the gasoline may be poured should be used.

Grade of Gasoline. For ordinary use, gasoline from 56 to 68 degrees test is most satisfactory. The former, called also stove gasoline, is the only kind obtainable now.

Obstruction in Needle Valve in Carburetor. In searching for a clogged gasoline line, it is well to unscrew the needle of the needle valve and then blow through the valve. This will remove particles of dirt that may be there.

INLET MANIFOLD DESIGN AND CONSTRUCTION

Changes in Manifold with Engine Developments. Notwithstanding the marked attention paid to minor details of design in the last three or four years, manufacturers have had no greater problem than that of vaporizing the fuel properly, quickly, and efficiently; this has led to considerable attention being given to inlet-manifold design. In the beginning, the inlet was a plain straight piece of

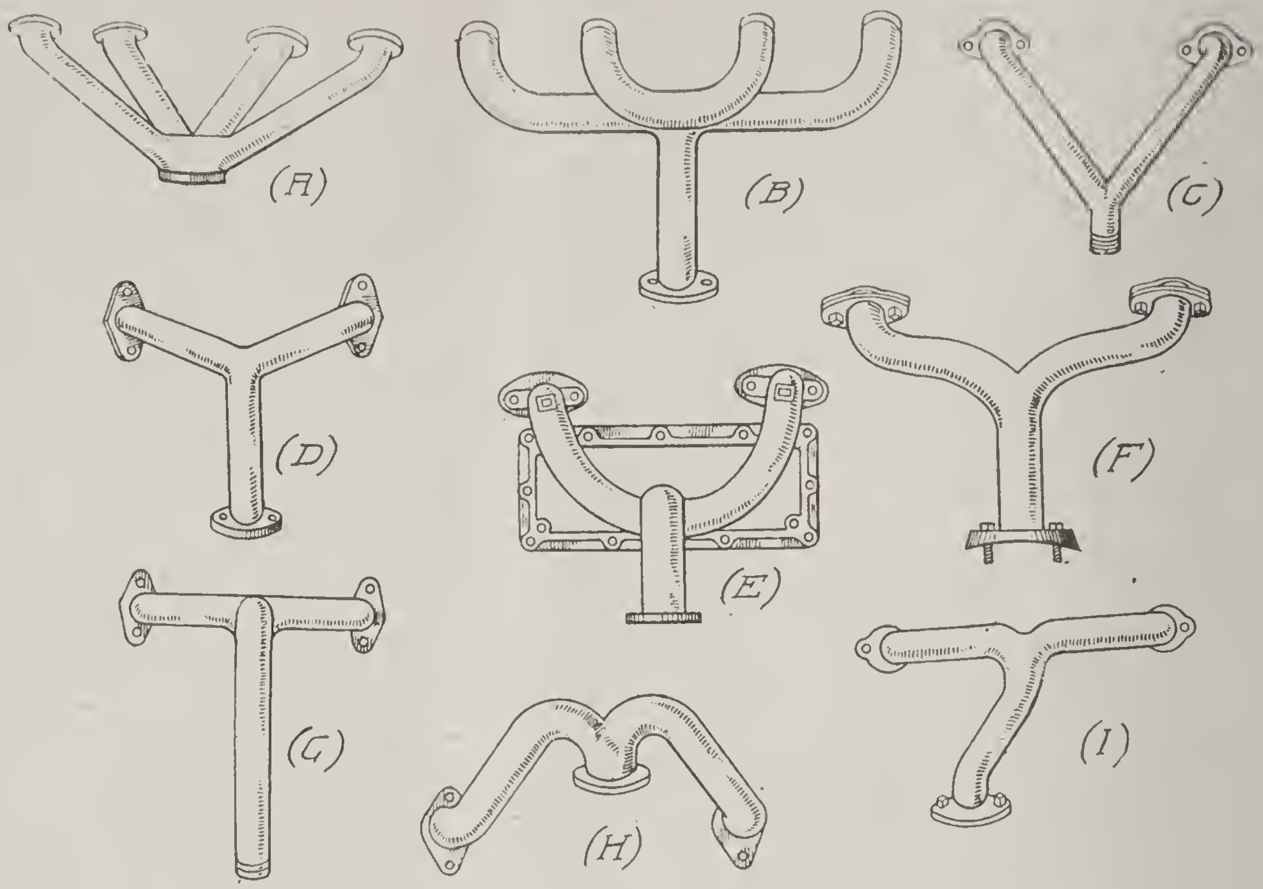


Fig. 139. Different Types of Inlet Manifolds for Four-Cylinder Engines
Courtesy of N. W. Henley Publishing Company, New York City

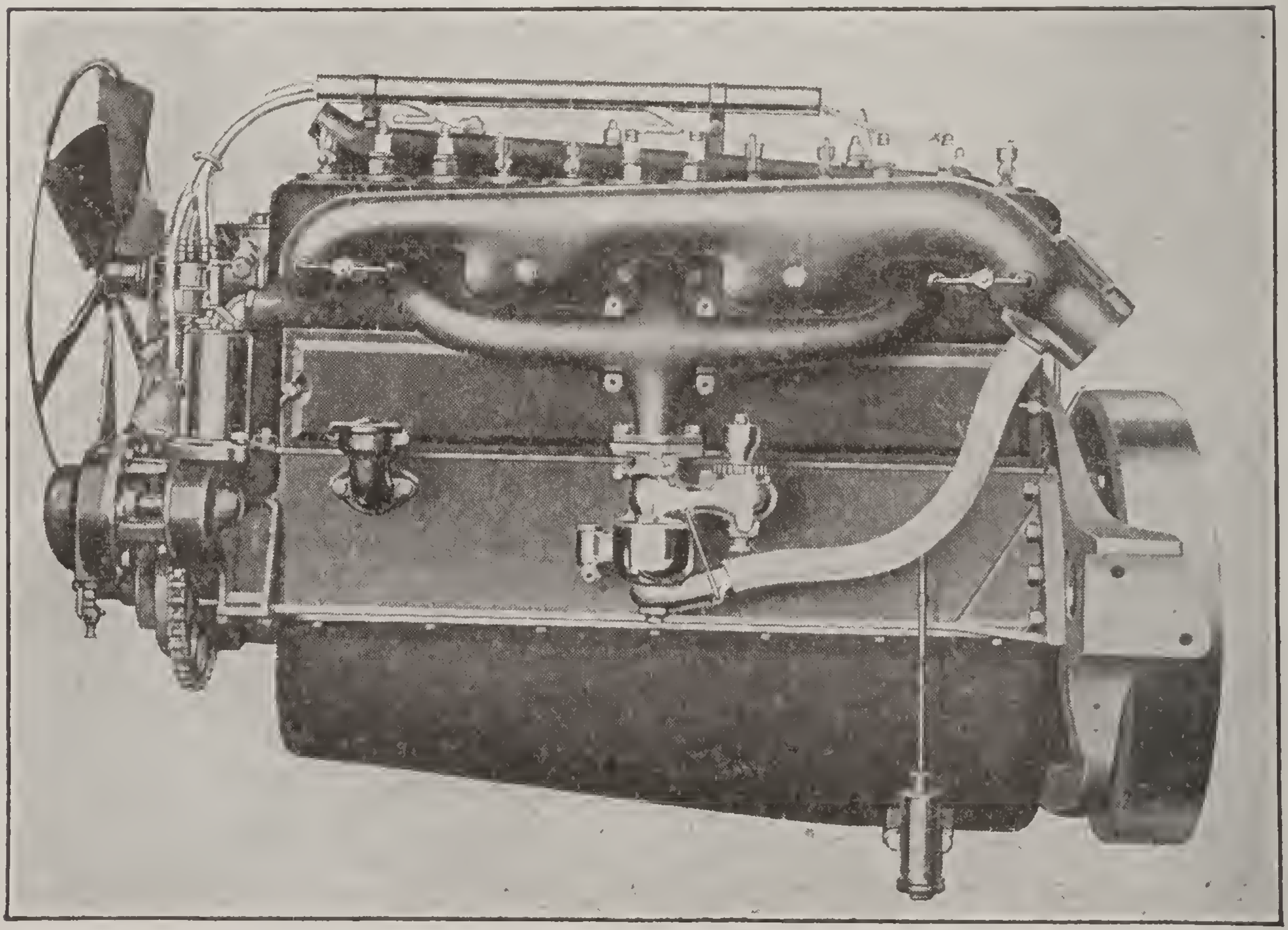


Fig. 140. Exterior of Studebaker Six Motor, Showing Particular Form of Inlet Manifold
Courtesy of Studebaker Corporation, Detroit, Michigan

tubing from what corresponded to the carburetor to the hole in the cylinder leading to the combustion chamber via the inlet valve. With the development of the four-cylinder motor, the majority of these were cast in pairs, and the pipe assumed a plain or modified Y-shape. Even at that, there was considerable chance for variety, as will be noted in the nine different forms shown in Fig. 139.

Changes from Fours to Sixes. With the coming into popularity of the six-cylinder form of motor, the inlet manifold received renewed attention; for now there were more variables, and it was a question of the best combination of them. One solution of this, as seen on a medium sized block six, is illustrated in Fig. 140. Here, the distance which the fuel must travel to the two central cylinders (cylinders *3* and *4*) is so much less than the distance which the gases must travel to either *1* and *2* at the front or *5* and *6* at the rear that there was the possibility of these four cylinders being somewhat starved. To compensate for this, the central part of the manifold where the three pipes to the cylinders join that from the carburetor was made much larger, with the idea of providing a well, or reservoir, for gaseous mixture large enough so the two central cylinders could not use all its contents.

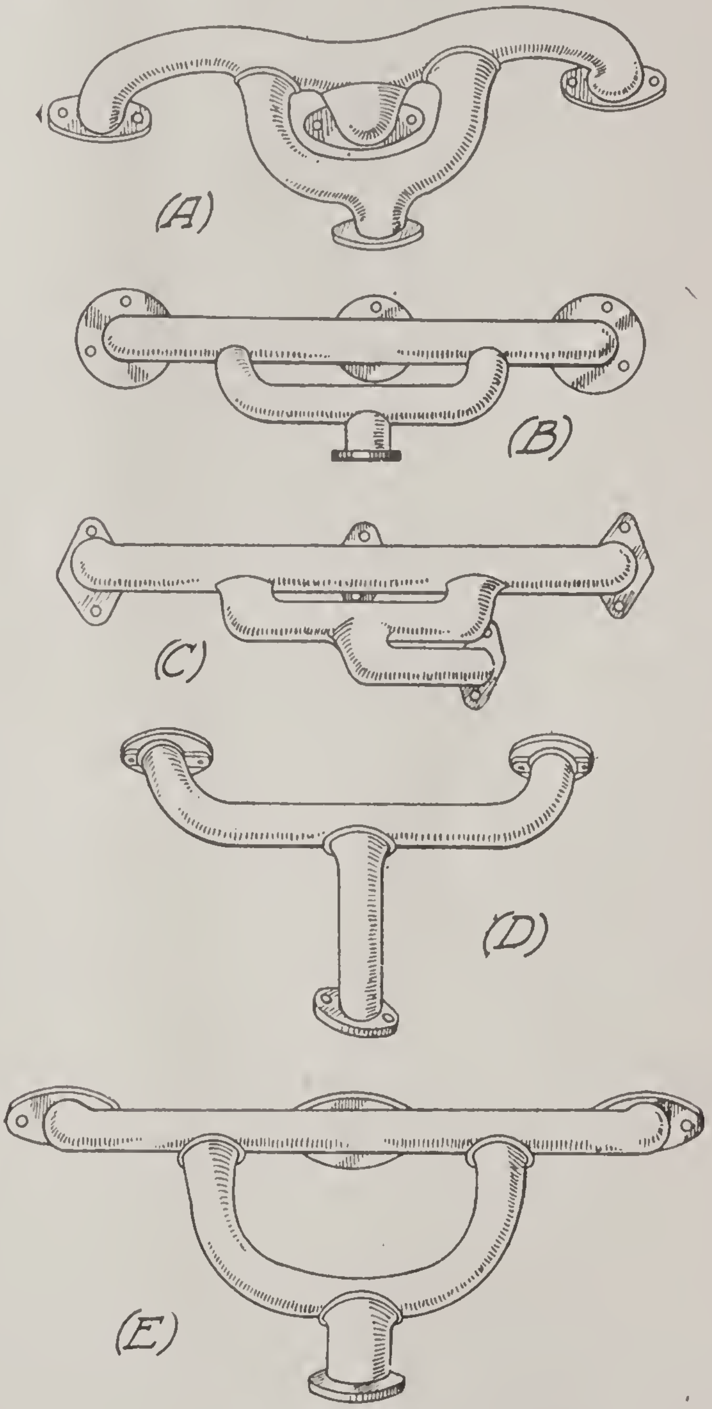


Fig. 141. Variety of Inlet Manifolds Used on Six-Cylinder Engines
Courtesy of N. W. Henley Publishing Company, New York City

The majority of designers, however, preferred to make the distance for the gases the same in each case, which led to some of the shapes seen in Fig. 141. Here it will be noted that a central loop is used to make these distances come out equal in all but one case; in that, the cylinders are cast in threes with a single inlet for each group.

Changes for Eights and Twelves. The coming of the V-type motors, both eights and twelves, has had another influence; for they came at the time when fuel was getting heavier and heavier. Designers were beginning to recognize the difficulty of vaporizing all the heavy fuel before it reached the cylinders, and, to assist in this, they began utilizing the manifold. Consequently, the majority, if not all, the eight- and twelve-cylinder engines have manifolds of the loop type shown in Fig. 142. The unusual diameter of this is due to the water jacket around it; the water inlet is seen at A and the outlet to the carburetor water jacket at B. In this form, the unusual height is due to two things: the necessity of getting the carburetor between it and the cylinders, yet not too close for accessibility; and of having a sufficient volume to act as a storage reservoir, since each side of this (each half of the loop) serves six cylinders (four in the case of the eight-cylinder engine). This is a typical eight- and twelve-cylinder manifold, except that many of them have a pair of pet cocks let into it for priming or cylinder testing purposes.

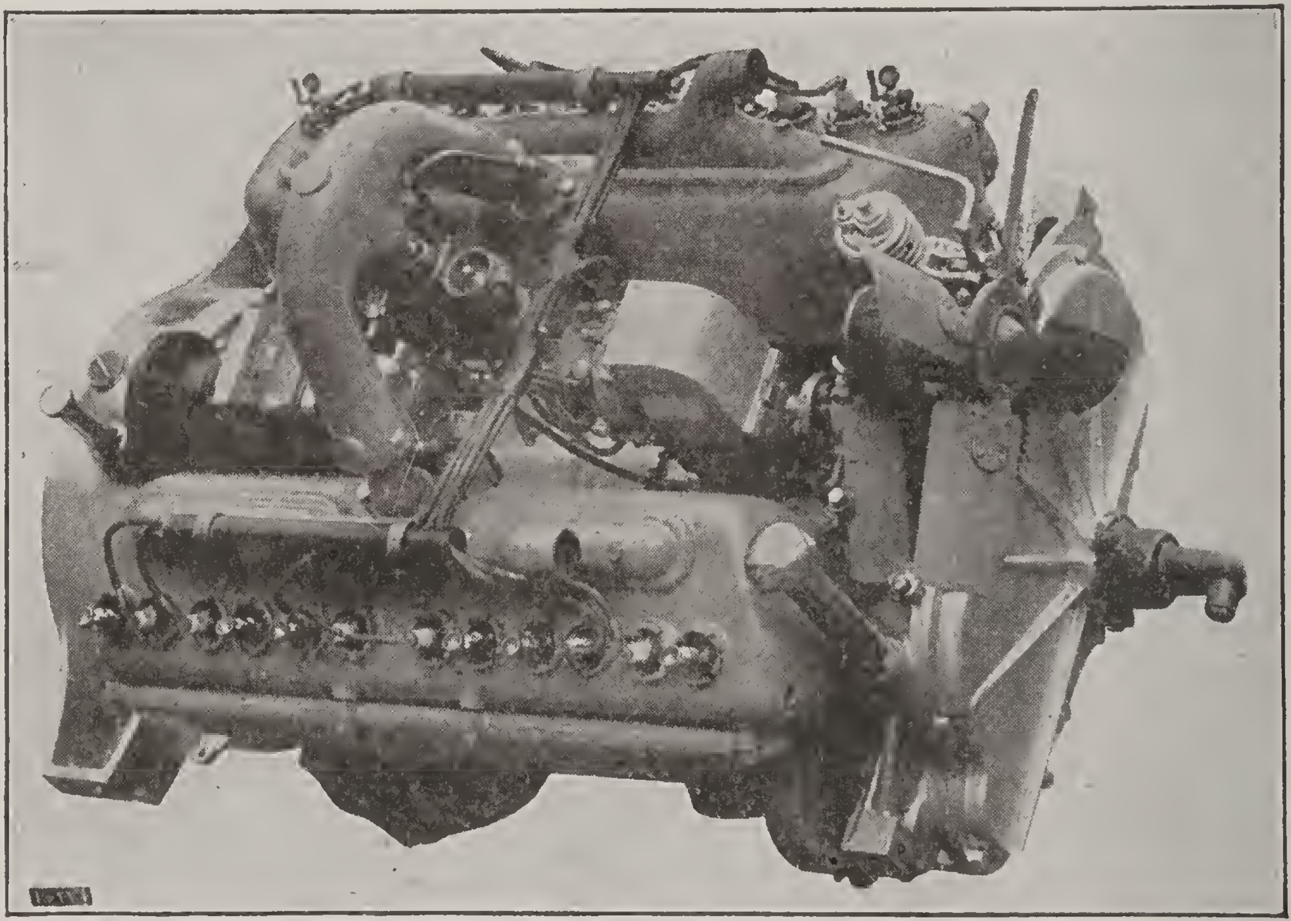


Fig. 142. View of National Twelve-Cylinder Motor from Above, Showing Inlet Manifold
Courtesy of National Motor Vehicle Company, Indianapolis, Indiana

Heating the Charge. The method of heating the charge has taken a number of forms. In a simple four-cylinder motor of the L-head type, like the Ford, it has been possible to develop a combination inlet and exhaust manifold (a single casting which would replace both of the former manifolds) which would give the heating effect desired in the inlet portion. Fig. 143 shows one way in which this is done and shows the central plate, or rib, between the two manifolds, which is heated to a high temperature by the exhaust gases, and thus has a large influence on the final vaporization of the inflowing gases on the other side of it. It is claimed for this form that it will save

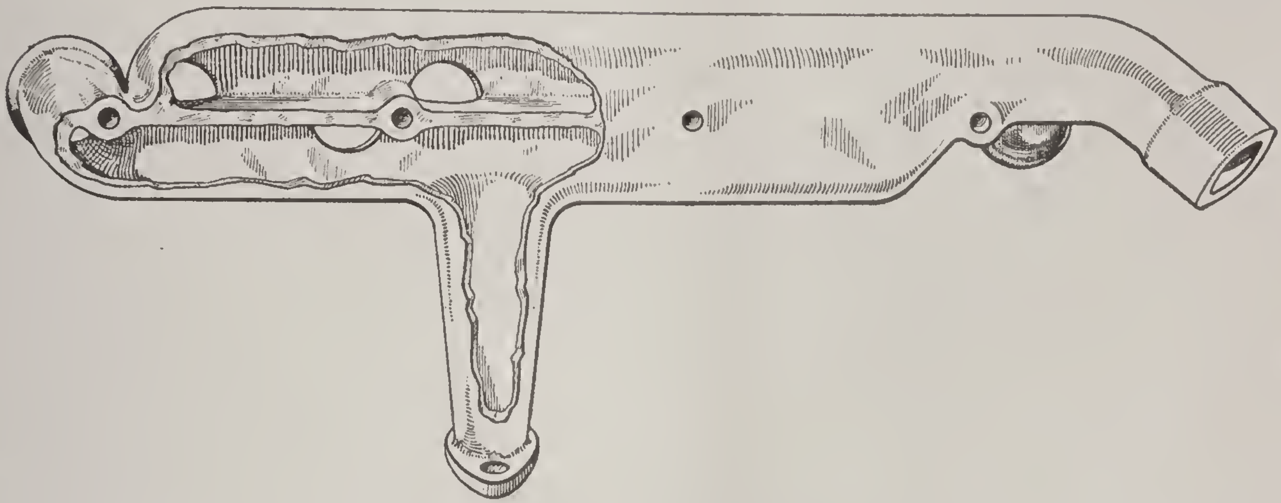


Fig. 143. Type of Combination Inlet and Exhaust Manifold Which Improves Vaporization

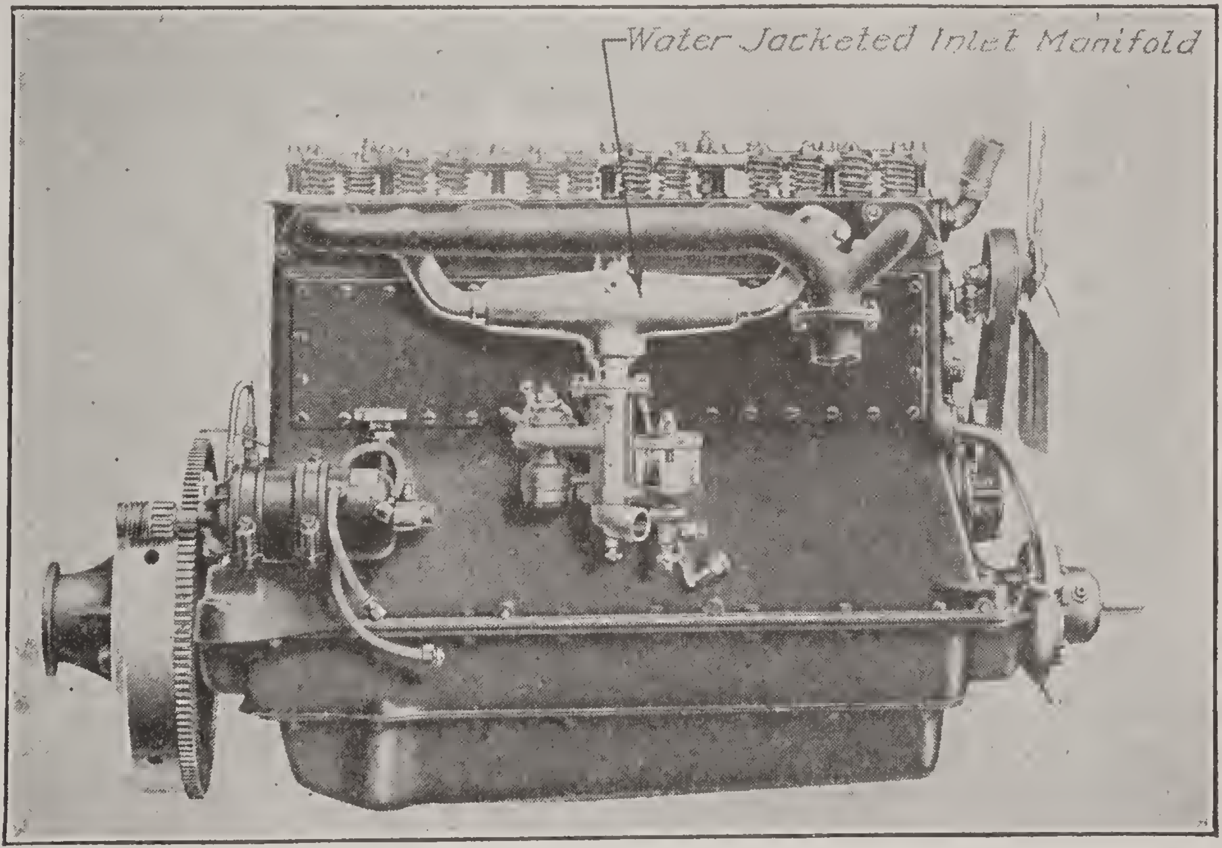


Fig. 144. Form of Water-Jacketed Inlet Manifold Used on Marmon Motor
Courtesy of Nordyke & Marmon Company, Indianapolis, Indiana

from 25 to 40 per cent of the fuel used, and, even though this claim is not borne out in all cases, the fact that there is a saving shows that this is a correct method. Many of the more modern motors are not only incorporating this as a method of saving fuel and increasing the motor's efficiency, but also of reducing the number of parts in the machine, the opportunities for trouble, and possibly of reducing weight.

Another way in which the ordinary four- and six-cylinder inlet manifold has been altered is by the addition of the water jacket, previously mentioned. A typical example of this is seen in Fig. 144, which shows a water-jacketed inlet manifold on a six-cylinder motor, although the water-pipe connections are not visible.

Changes in Construction of Manifold. In addition to the design, the construction of inlet manifolds has been of marked influence. Thus a manifold of aluminum, iron, or other cast metal is usually quite different from what a manifold for the same engine would be if made from copper or steel tubing. In addition to the limitations of the process of production, there would be the changes which the surface produced would have. Thus, a casting would have a more or less rough surface, while a drawn tube would be perfectly smooth. This allows the use of a slightly smaller diameter and more abrupt bends with the latter than with the former. Similarly, the fastening means have had an influence. On a number of block-cast motors, the manifolds have been cast integral with the cylinders, thus taking further advantage of the heat generated within the motor, for fuel vaporizing purposes. It is for this type of motor that the horizontal-outlet type of carburetor has been developed. In this type the volume of vaporizing space beyond the spray nozzle is at a minimum, that is, they have been designed simply to mix the fuel spray and air, while the highly heated inlet passages do the actual vaporizing.

Hot Spots in Manifolds. A later trend in inlet manifold has to do with easier vaporization of the heavier fuels of today. Due to the high boiling point an external source of heat has been found necessary in this, and one of the ways in which this has been done is by means of the "hot-spot" manifold. To explain this simply, the inlet manifold is so constructed that a portion of it consisting of solid metal is in constant contact with the exhaust manifold so that in continuous running this solid metal in the intake manifold becomes heated, perhaps to a high degree. Furthermore, this "hot-spot" is so located in the inlet passages that all fuel must pass over it before passing to the cylinders, that is the last thing before passing in. A sharp bend in the inlet passage at this point does it, with the result that any unvaporized particles remaining in the fuel gas at this point are thrown against this highly heated spot and vaporized there, instead of being carried into the cylinders as liquid particles, as would be the case without this heated spot. One of these using the Stromberg "L" carburetor is that of the Chalmers, shown in Fig. 144 A, said to produce more power, greater economy, and more rapid acceleration.

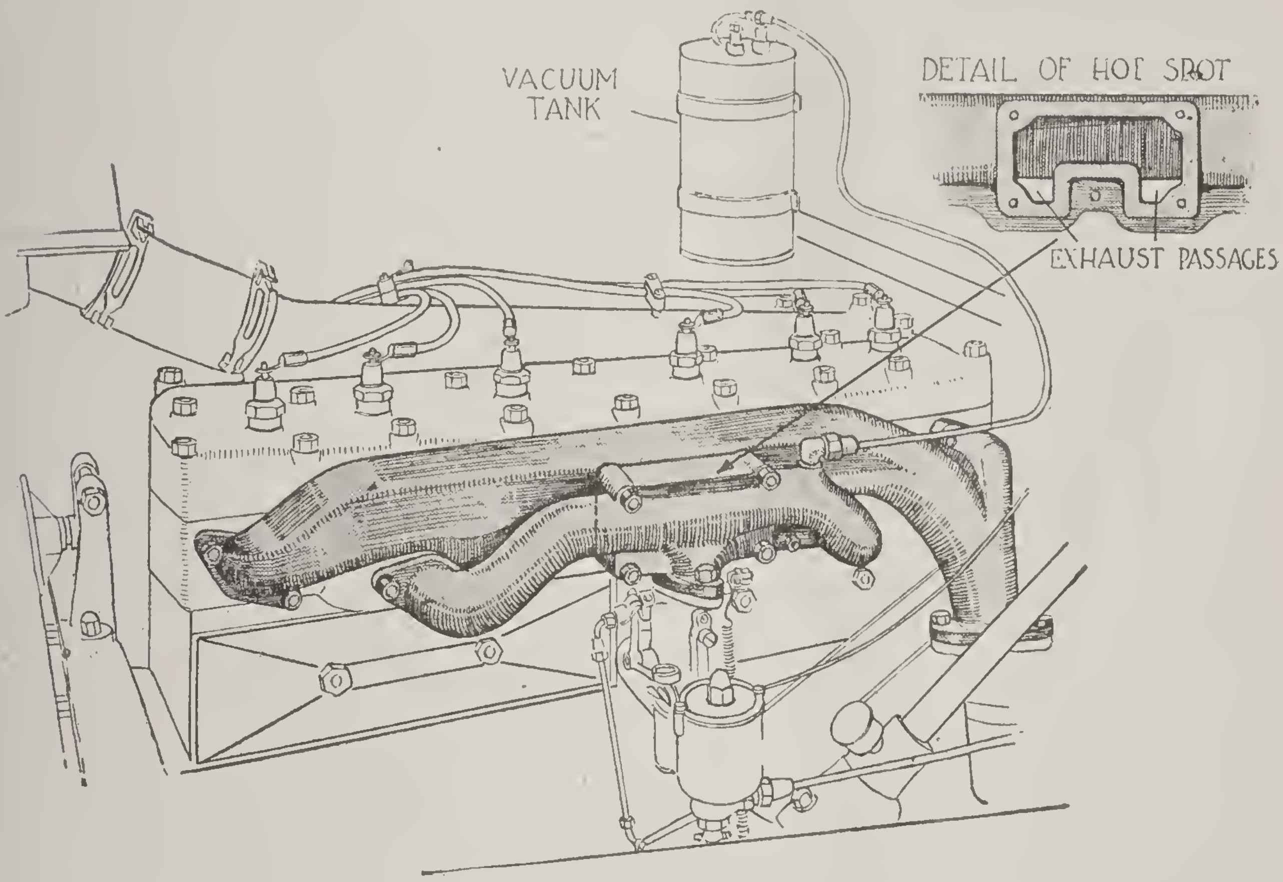


Fig. 144 A. Chalmers Hot-Spot Inlet Manifold
Courtesy Automotive Industries, New York

Another similar arrangement is used on the Hinkley truck engine as shown in Fig. 144 B. This engine is really a modification of the Class B Government engine and resembles it very closely. As will be noted in the drawing, this arrangement is very similar to the Chalmers, the exhaust and inlet being slightly different to facilitate easy and quick removal and replacement.

As has been stated frequently, much heavy fuel is available on the Pacific Coast and at low prices, so out there considerable effort has been expended on using these cheaper but heavier fuels. A modification of the hot-spot arrangement, designed to be used on Ford cars is shown in sketch form in Fig. 144 C. Here the hot spot projecting into the exhaust manifold is not alone made very large but the outer or heating surface is increased by the addition of fins similar to an air-cooled engine. This adds metal to heat up and hold the heat, which is what the heavier fuels like distillate must have. In addition, as will be noted, the carburetor is so constructed as to spray all the fuel oil directly into the interior of this highly heated mass of metal, the gasified parts coming down into the intake manifold. This heated mass of metal is thus the entire dependence for vaporization in this case, the actual carburetor part of the device having been eliminated. It would seem that this carries the hot-spot or hot surface plan almost too far, its original intention having been for use as an auxiliary solely, the hot surface vaporizing only those heavy globules of the liquid which the spraying and atomizing and air mixing did not or could

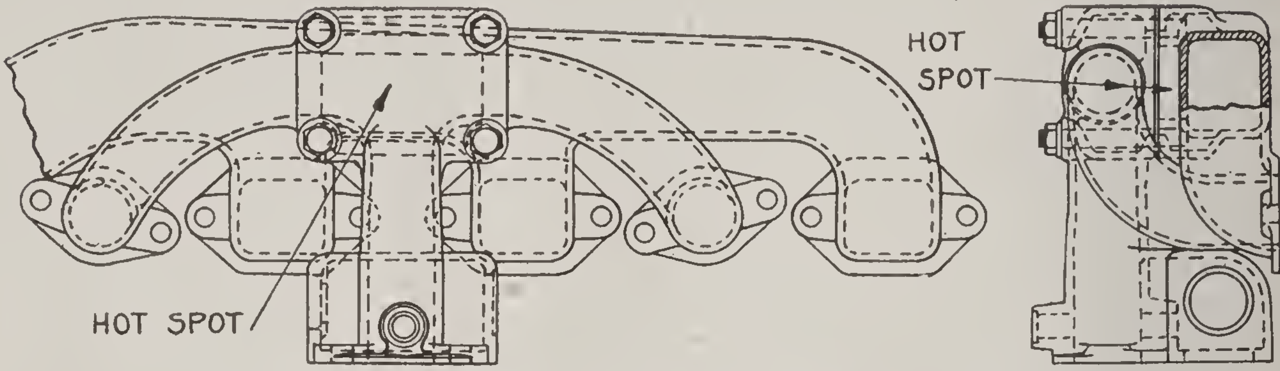


Fig. 144 B. Hot Spot Manifold Arrangement on Hinkley Truck Engine
Courtesy Hinkley Motors Corporation, Detroit, Michigan

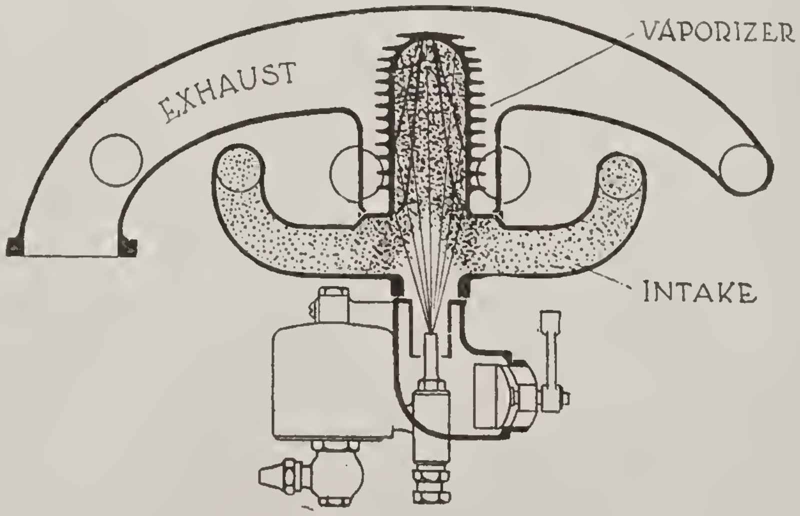


Fig. 144 C. Far-Western Carburetor Which Is All Hot Spot

not break up and vaporize. In short it was intended originally only as a clean-up device, following and wholly dependent upon the carburetor. The device in Fig. 144 C aims to make the hot surface become hot surface, vaporizer and clean-up device all in one.

Another version of the heated manifold surface is shown in Fig. 144 D, the manifolds of the Velie tractor. Here the first part of the inlet manifold is highly heated by constructing the two manifolds as one, the inlet consisting of a straight vertical passage through the center of the exhaust passages, just as the detail at the left shows. This would give the high heat necessary for the original vaporization or cracking up of all the fuel, but to insure continuation of this condition, that is, to prevent any of the mixture condensing out into liquid again, the second portion across the top of the cylinders is water cooled. In this condition, the gas would be too hot to enter the cylinders, hence it is cooled by means of air-cooling fins or ribs along the last portion of its length. As a permanent gas has been produced by the previous steps, this carries with it small possibility of any condensation.

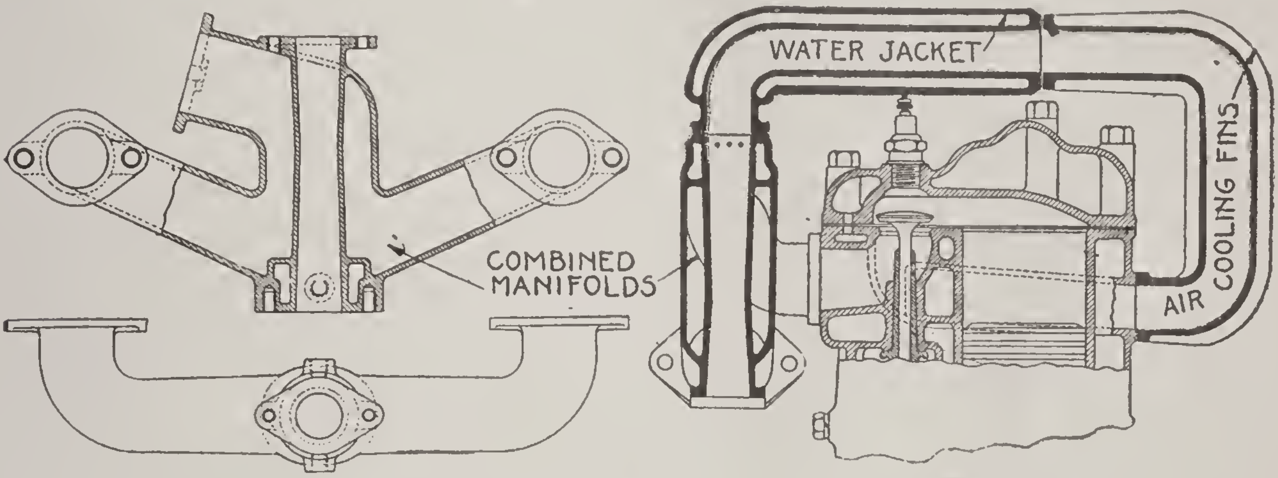


Fig. 144 D. Combined Inlet and Exhaust Manifold of Velie Tractor
Courtesy Velie Motors Corporation, Moline, Illinois

The real flaw in the hot surface method is that it is of no help whatever in starting, since it does not begin to work until after the engine has run for some time, and heated up. And poor starting is really more drawback than running on heavier fuels.

Inlet Manifold Troubles. The principal inlet manifold troubles are air leaks, which dilute the mixture beyond the carburetor, making it and its many elaborate adjustments more or less useless. These leaks may be due to leaks around joints, connections, or gaskets or to porous castings. If the inlet manifold is of copper or steel tubing, the idea of a leak can be dismissed, but, otherwise, a porous pipe can be discovered at idling speeds by squirting gasoline upon the suspected surface of the manifold and noting if the motor speeds up. If it does, this is a sign that some of the gasoline has been drawn through the holes in the manifold, enriching the mixture.

The leaks around joints, connections, or gaskets can be found in much the same way. When the leak is found, the joint should be tightened if possible, or a new gasket should be put in, or both. In the case of the porous manifold casting, it can be painted with a fairly heavy paint while hot so that the pores of the metal are well opened. Then, after this has dried in thoroughly, another coat will probably finish the job. If this does not prove to be the case, special cement for filling porous castings can be purchased and applied; or, best of all, if the case is a bad one, an entirely new manifold should be put in.

FUEL SUPPLY

For storage of the fuel required for the propulsion of a car and for feeding the fuel to the carburetor, many different systems are in use.

Tank Placing. In automobiles, the gasoline tanks are generally placed under the front or rear seats, or under the frame at the rear. In many types of runabouts and roadsters, the tank is placed above the frame at the rear.

Fuel Feeding. When the tank is at the rear, or when it is under the front or rear seat, no special provision is necessary, under ordinary circumstances, to insure a positive flow of the liquid fuel to the carburetor.

Gravity. With the tanks placed high, the gasoline can be depended upon to run down to the float chamber by gravity. In mountainous districts it is sometimes found, in climbing very steep hills, that the angle becomes such that the fuel will not flow, especially when the tanks are under or back of the rear seat, or when they are nearly empty.

A means of getting around this difficulty is to place an auxiliary tank of one or two gallons capacity on the front of the dashboard, behind the engine and under the bonnet, and run a pipe direct from it to the carburetor. When the car is in a level position, this auxiliary tank fills automatically from the main tank, but a simple valve prevents the contents of the auxiliary tank from running back when the machine is tilted up. In this way a sufficient supply for 15 or 20 miles running is placed in a position to reach the carburetor under any possible road condition.

Air Pressure. With the tanks placed low, whether under the frame or above it, it is necessary to feed the fuel to the carburetor by more positive means than gravity. One of the commonest systems involves pumping a low air pressure into the tank above the fuel, so that this pressure forces the liquid out regardless of the relative heights of tank and carburetor. Ordinarily, a small hand pump is sufficient to provide such air pressure, though in modern automobiles equipped with compressed-air starting devices, or compressed-air tanks for filling the tires, provisions can be readily made for supplying the tanks with air from these sources for the purpose of feeding the fuel.

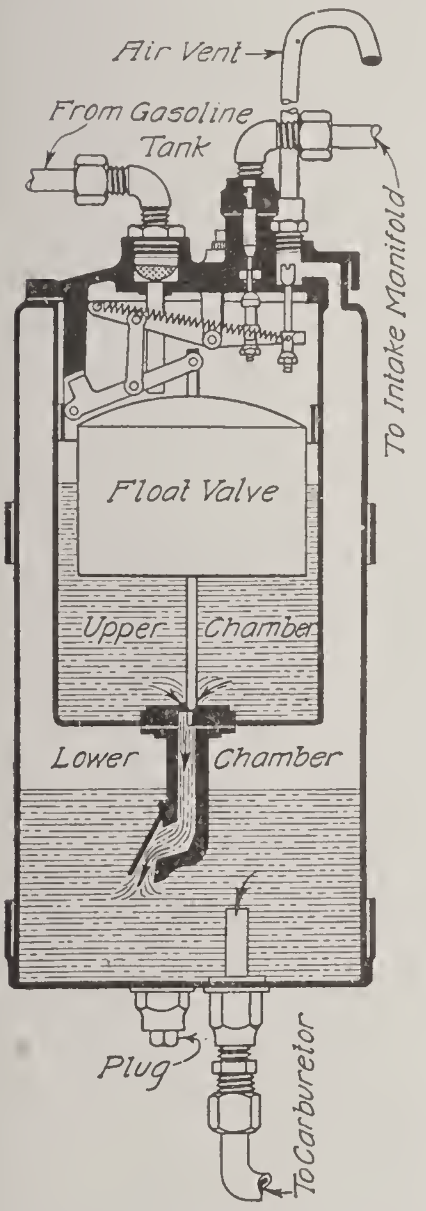


Fig. 145. Section through the Stewart Vacuum Gasoline Feed Device

Exhaust Pressure. A system that is much used for providing pressure in the fuel tanks, though not so highly regarded as in the past, is to tap the exhaust piping and to take from the connection a pipe line that permits the entry of a certain amount of the exhaust gases into the fuel tank. A simple automatic valve controls the pressure and shuts off the admission of gas when the pressure rises above the very low maximum required. In a system of this character there is no possible danger of fire, not only because the exhaust gas is very quickly cooled in passing through a length of small piping, but also because the contents of a gasoline tank is ordinarily not ignitiable, because of the lack of any air to support the combustion.

Sooting up of the automatic valve is the commonest trouble with this system.

New Vacuum Feed Device. The many troubles incident to the use of the rear tank location with pressure feed have brought about the production of a new device, which is called the Stewart vacuum feed. This is a small compact circular unit, which is placed on the dash under the hood for use with a rear tank and, when so used, eliminates the pressure feed. A sectional drawing of this is shown in Fig. 145. It may be described as follows: There are three connections at the top, one to the gasoline tank, one to the intake manifold, and one to the air vent. Through the medium of the intake-manifold connection, the motor suction is communicated to the tank, for that is what the device amounts to. This produces a vacuum and opens the valve connecting with the gasoline tank. That, as well as the connecting-pipe line, being air tight, gasoline is drawn in to fill the vacuum, flowing into the upper chamber with which the gasoline tank communicates.

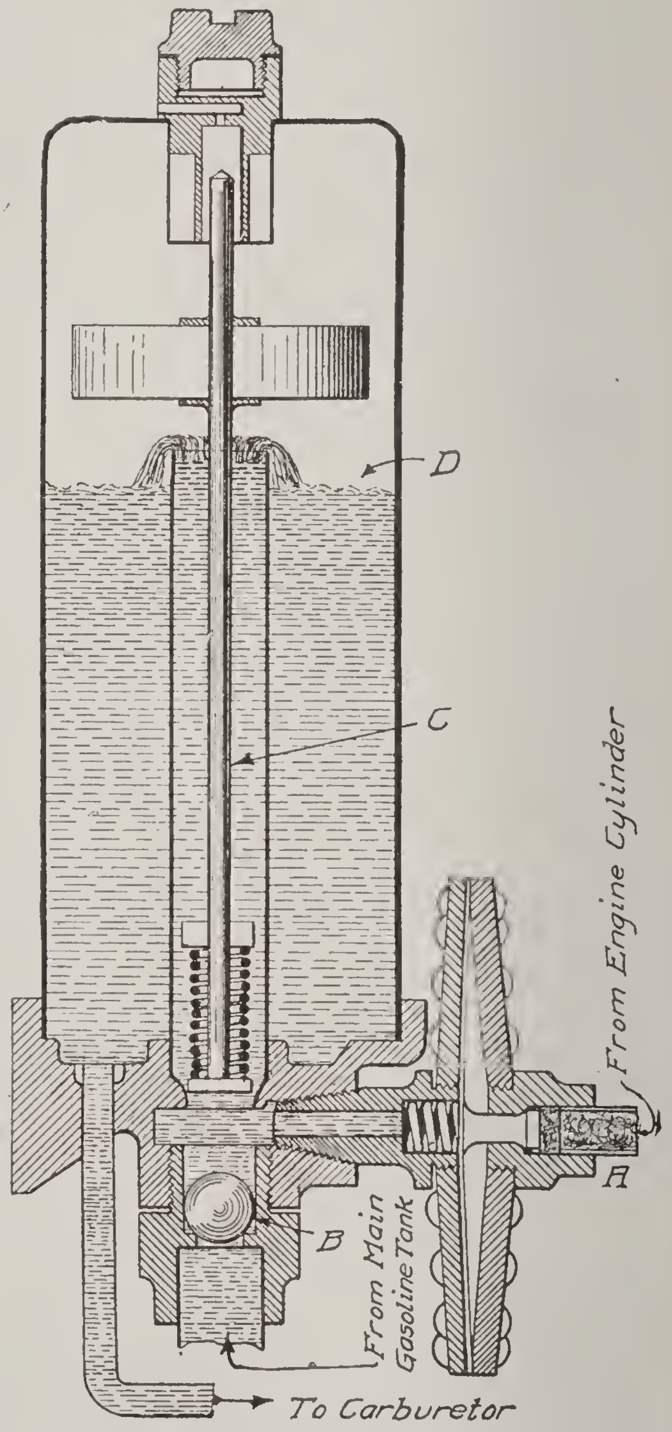


Fig. 146. Section through Carter Automatic Gravity Fuel Tank
Courtesy of Carter Carburetor Company, St. Louis, Missouri

This has a valve connection to the lower chamber, operated by means of a float; it in turn is controlled by the intake manifold suction, through the medium of the system of levers. By it, the lower chamber is kept filled to a fairly high level, whence feed to the carburetor is by gravity. This method thus does away with all the troubles of the pressure system, at the same time allowing of the accessible and advantageous rear tank location. It is placed as high as possible on the inside of the dash under the hood, hence there is never any trouble with the gravity feed even on the steepest hill. In one test, this vacuum-feed device increased the mileage of the car per gallon of fuel by more than 22 per cent.

Pressure-Operated Feed Device. Carter System. Since the introduction of the Stewart device described above, a number of devices acting on somewhat different principles have been brought out. In the Carter automatic gravity tank, as it is called, the suction and compression strokes of the motor are used to furnish the pressure which operates a simple diaphragm pump, first in one direction, then in the other. This diaphragm pump is shown at the right of Fig. 146 and is marked *A*. As shown, this connects through a ball check valve *B* with the main gasoline tank, the strokes of the diaphragm pump drawing fuel into the central well *C*, which, when filled, overflows into the main tank space *D*. From here it flows by gravity through the pipe *E* to the carburetor. The tank is made in but one size, that holding about a pint. Above the ball check, a spring-operated valve of simple design prevents the fuel from flowing out when the ball has been drawn off its seat. As the tank gets very full, the float will rise, and the needle at the upper end of its stem will seat at the top, cutting off the air supply. Without any air in the opening tank, an internal pressure will be created which resists the opening of the valves and thus the further supply of fuel until more has been drawn off and the float drops down and uncovers the air hole again.

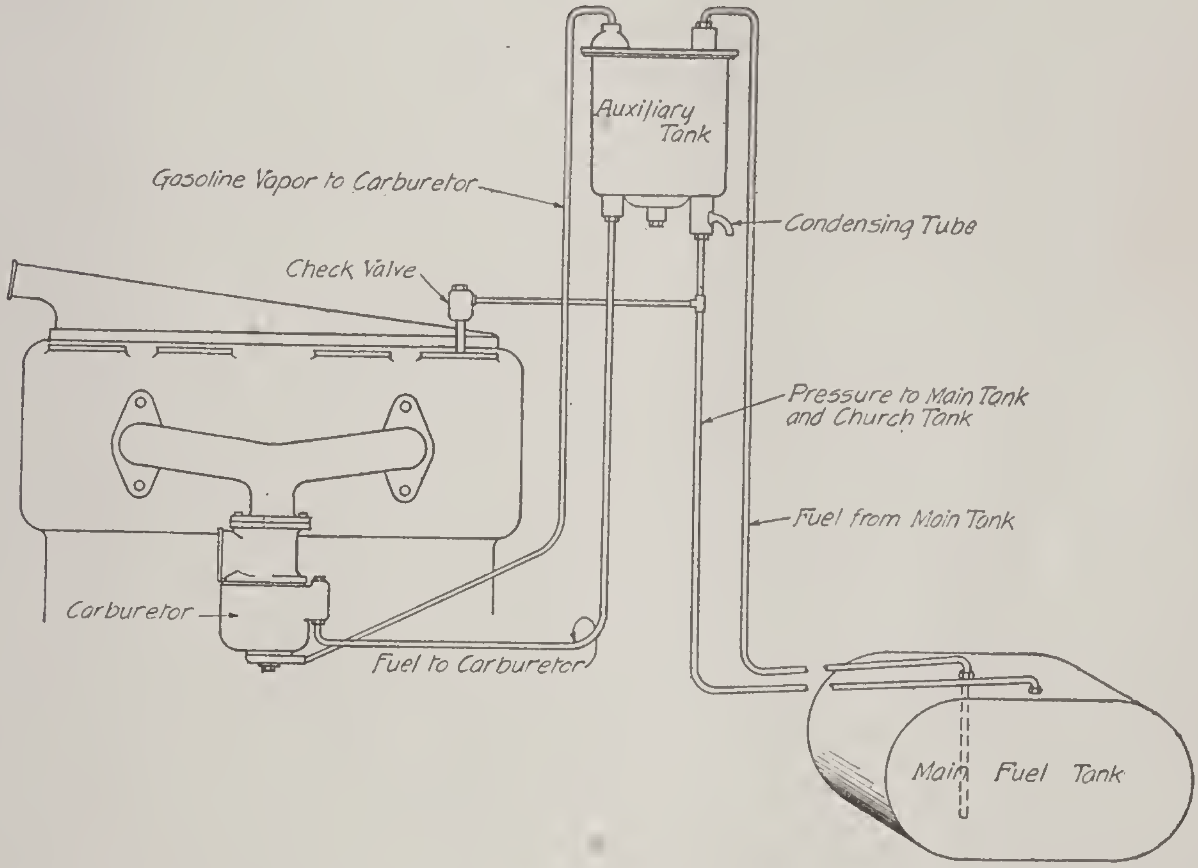


Fig. 147. General Layout of Church Fuel Supply System as Applied to a Car
Courtesy of Automatic Carburetor Company, Chicago, Illinois

It is advised that this tank be connected to the engine in any convenient place, except that near the exhaust manifold. When the tank has been connected and is ready for use, prime it with about half a pint of gasoline poured in through the filler cup on the top. After this has been done, the tank will continue to operate as long as there is fuel in the rear tank.

Church System. In the Church system, the compression, or explosion pressure, is used to lift the fuel through the medium of the specially designed check valve. A general layout is shown in Fig. 147, in which it will be noted that the check valve is mounted in the rear cylinder in place of the pet cock. Through this, the pressure is maintained in the main tank at the rear of the chassis, thus forcing gasoline to the auxiliary tank. Normally, the check valve will produce about one and one-half pounds pressure on the main tank, but the arrangement of the system is such that this maximum pressure is automatically increased to meet the conditions existing at any time. In this sketch, it will be noted that the pressure line is constructed with a **T**, one part of the pressure going to the auxiliary tank where it is regulated by means of a float, and the other going to the main fuel tank.

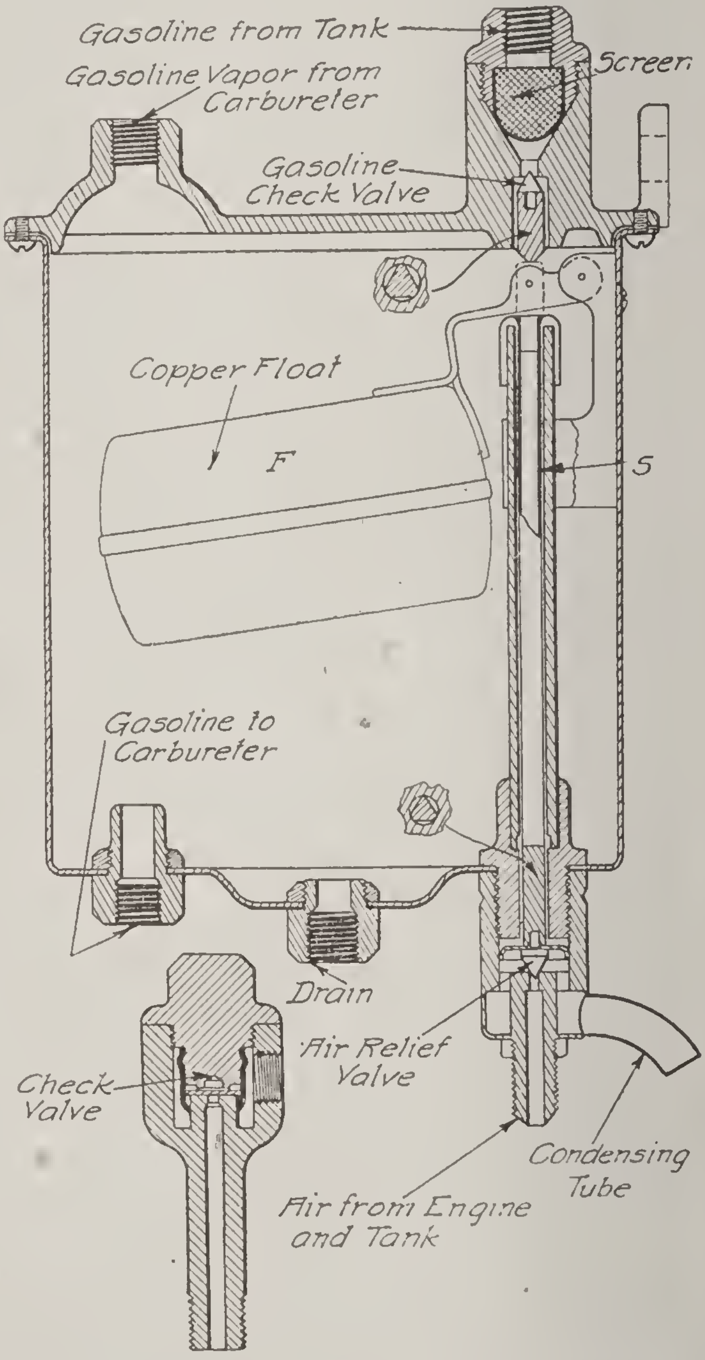


Fig. 148. Section through Church Tank, Showing Construction; Also Section of Check Valve

By referring to Fig. 148, which shows a section through the auxiliary tank, the regulation of the pressure will be made clear. When the supply in the auxiliary tank gets low, the float *F* drops down; this moves the rod *S* down also. The downward movement of the rod forces down the valve *R*, which prevents the air escaping through the condensing tube, and thus the entire pressure in the system is exerted upon the main tank with the result that the pressure rises there. When more fuel is forced to the auxiliary tank, the float rises and allows the air relief valve *R* to rise; this opens the passage to the condensing tube again, so that the air can escape in that way and relieve the pressure upon the main tank. In this way, a balancing effect is produced, which automatically keeps the auxiliary tank well supplied.

From this tank the fuel flows by gravity to the carburetor. There is, however, an additional and valuable feature of this system. On top of the tank will be found a vapor outlet *O*, and in the sketch it will be noted that this is connected back to the carburetor. In this way any vaporization which occurs in the auxiliary tank is utilized. This has the double advantage of being a source of economy and of keeping the system closed against the entrance of dust. Provision is made, despite this, for cleansing out sediment, by a drain plug at the bottom of the tank. The gasoline check valve will be noted at the top, this operates in conjunction with the float stem and air-relief valve, that is, the rising of the float in a full tank will automatically cut off further supply by means of the check valve, as well as by opening the air-relief valve at the bottom. Similarly, the downward movement of the float, which closes the air valve and causes more fuel to be forced into the tank, automatically opens the gasoline valve so this fuel can flow in. The enormous reduction of pressure eliminates all possibility of danger which might be thought of in connection with the mingling of exhaust gases and gasoline, their temperature being reduced simultaneously with the reduction in pressure.

Fuel Pumps. In a few automobiles, the expedient of providing a small motor-driven gasoline pump has been tried in place of the carburetor with a float chamber. As long as the engine is running, the pump forces an excess of gasoline from the tank through the carburetor chamber, from whence the surplus is returned to the tank through an overflow, placed at a certain height so as to constantly maintain a proper level.

Piping and Connections. In arranging the piping system for the fuel supply of a gasoline automobile, the first essential is to use a soft brass or copper tubing that can be depended upon not to break from the vibration to which it is subjected.

As a further safeguard against breakage, and to allow alterations in the relative positions of different parts, due either to the straining of the machine while it is in use or to a change of adjustments when it is disassembled or reassembled, loops or coils introduced at proper points in a pipe line are of great advantage.

Stop cocks close to the tanks are an excellent safeguard against fire, since they permit the shutting off of the fuel supply in the case of any breaks in the line. Such safeguards should always be provided.

With reference to the pressure system of fuel feed, there is hardly any limit to the precautions which must be taken to avoid leaks. The smallest leak puts the system out of commission as soon as the pressure leaks down to a point where the fuel will not rise to the carburetor. When this occurs, the engine cannot be operated until the leak is found and fixed. To avoid leaks, many drivers go over all joints frequently and likewise replace all old packing. In addition, they wipe the joints with soap to prevent leakage and then cover them on the outside with tire tape or similar flexible material which can be wound on in such a way as to stay permanently. The rapid adoption of the Stewart device, since it was brought out in 1914, shows better than anything else how troublesome was the pressure-feed system. Statistics for 1914 cars showed that in 237 different models, 109 had the gravity tank under the seat, and 31 in the cowl, this making 140 with gravity feed, leaving 97 with the rear-pressure tank location. Similar statistics for 1915 show 52 per cent in favor of the rear tank location, while 1916 shows almost 66 per cent with rear location, and 34 per cent vacuum fed.

Reserve Tanks. To guard against the annoying mishap of having the gasoline give out while an automobile is in use, perhaps remote from any source of supply, many cars are now provided with reserve tanks which hold back one or two gallons of gasoline. This reserve cannot be used except when it is fed into the system through the deliberate intent of the operator.

In its simplest and one of its best forms, a reserve tank takes the shape of a partitioned-off portion of the main tank, into which the gasoline automatically flows through an opening at the top when the tank is filled. It cannot pass to the carburetor until a special valve in the bottom is opened and the fuel allowed to flow back into the main tank.

A later and even more simple provision is the use for the gasoline tank of a three-way outlet cock which has a fairly long extension up into the tank. The extension tube is open at the top and has a hole near the bottom of the tank which communicates through a branch tube with the third way of the cock. When the outlet cock is set for normal flow, the fuel feeds until the level reaches the top of the extension; at that point it stops flowing. This is the warning to the driver that his fuel is low. Then all he has to do is to turn the outlet cock to the other position, thus allowing the fuel to feed from the bottom hole of the extension tube. The remainder of the fuel, that is, the amount represented by the difference in level between the top and bottom of the extension tube, will carry the car to the next fuel station.

Fuel Gages. The development of depth and quantity indicators has received much attention in the last few years, with the result that practically all new cars have some form of gage on, or in, the fuel system. On rear-pressure tanks, it is usually located on the tank, so the driver must go to the rear of the car to see how much fuel he has left, but on cowl tanks or those located under the seat, it is possible to have the gage set on the instrument board or the dash, as the case may be, so that it is in plain sight. Practically all the gages give indications in gallons and fractions, so that with the gasoline gage and odometer in front of him, and knowing how many miles he averages to the gallon of fuel, no driver need worry about having gas. He can readily figure ahead and keep sufficient on hand for his needs. A device has been produced to give dashboard indication of rear-tank capacities, but this is so complicated and expensive that it is little used.

FUEL SYSTEM TROUBLES AND REPAIRS

Failure of Fuel to Flow from Full Gravity Tank. Many times the fuel will not flow from a gravity tank which is full. This may be because the air holes in the filler have been stopped up so that no air can enter. By cleaning out the holes, if there are any, drilling some if there are not, or by loosening the filler, this can be remedied. For this reason, it is well not to use a gasket or washer on a gravity tank. On a pressure tank, just the reverse situation exists, and it is advisable to use a rubber or leather washer at the filler cap.

Fuel Line Obstructed. Many times an obstruction in the fuel line will be found at a very low point or sharp bend, where dirt in the fuel has gradually collected until there was enough to cut off the flow. A good way out of such a difficulty is to close connections at the tank and at the carburetor, take the entire fuel line off and blow it out with compressed air. This will clean it thoroughly.

Lock on Fuel Line. The garage or repair man can insert a very efficient lock on any car by putting into the fuel line at a convenient point a shut-off cock which works with a removable key. These are readily obtained, and any good workman can install one in a couple of hours. Many owners of cars would be glad of an efficient lock and would be willing to pay well for one. This one has the advantage of being simple, cheap, and effective.

SUMMARY OF CARBURETOR INSTRUCTIONS

Q. What is a carburetor?

A. A carburetor is a device for vaporizing liquid fuels, and for adding to them, when vaporized, the proper amount of air for immediate and complete combustion.

Q. How many types of carburetors are there?

A. Three: the surface form, now out of date; the filtering type, no longer used, except on one or two English cars; and the spraying type, to which all modern devices belong. The first was useful only with the very light and extremely volatile fuels of ten and twenty years ago.

Q. What are the essential units of a spraying type of carburetor?

A. The essential parts of a spraying type of carburetor are: a float chamber with a float arranged to regulate the level of the inflowing fuel; a needle and nozzle, or spraying device, which should preferably be adjustable; an air opening, which may be variable or not, which may be in multiple form or not, which may have automatic valves to regulate its size or not; and a throttle valve to control the quantity of mixture passed into the cylinders. As an important auxiliary, the needle, nozzle, or spraying device, whatever its form, should be placed in a special vaporizing chamber, of a size and shape to give the best results.

Q. Do all these appear in all modern carburetors?

A. Practically all, in one form or another, and also a considerable number of additional parts. Thus many carburetors have two or more nozzles, or spraying devices; quite a few have two air openings, one of which is controlled by an automatic valve, some have three air openings; many, in fact most, of the modern devices have a method of heating the vaporizing chamber, or the space immediately above or below it, so as to facilitate complete vaporization, as well as to quicken the action; some have air valves in the form of steel balls; others have pistons and dash pots to eliminate sudden movements or changes in operation; many have auxiliary devices intended to give a special starting mixture; practically all have removable strainers for cleaning the fuel, some having two different forms of strainer.

Q. What is the generally accepted form of needle valve, or spraying nozzle?

A. There is no one accepted form, although the majority of carburetors have spraying nozzles, or needle valves, which come into one of four classifications. These are: the hollow nozzle with an opening at the top, slightly smaller in inside diameter than in outside, so that the spray of fuel is opened out in a fan-like form; the same form with an internal needle having a long tapered point and screwing up into it from below, this giving a means of adjustment which the plain hole does not; the same plain tube and hole, with an external needle having a tapered point and screwing down into it from above (in this, the body of the needle divides the spray of fuel); and the form of hollow nozzle in which the fuel is forced to flow outward through a series of holes, then upward to an outlet which consists either of an additional series of holes or a very fine annular ring. Either form gives the same result, a very fine and somewhat extended spray of fuel. The last form is sometimes modified to the extent that this annular ring of fuel, where it emerges into the vaporizing chamber, is as much as 3 or 4 inches in diameter.

Q. What is the purpose of the auxiliary air valve?

A. To supply additional or auxiliary air at the higher and highest speeds. Without this, the heavy suction of high speeds or hard pulling is very likely to produce too rich a mixture, that is, a mixture with too much fuel and too little air.

Q. Is there any disadvantage in this?

A. Yes. It has been found by experience that a motor will not operate well or give its extreme power or greatest speed on a rich mixture. Rather, at its highest output, the mixture should tend toward leanness.

Q. How does the auxiliary air valve remedy this?

A. By adding air when the motor suction gets strong enough to open the auxiliary air valve, the amount added being in direct proportion to the strength of the suction.

Q. What other disadvantage is there in over rich mixtures for high speeds?

A. An over rich mixture at high speeds shows a noticeable lack of economy, as at these speeds a great amount of gas is being used, and, if too rich, the gasoline fuel is being used up very rapidly. The makers of practically any carburetor equipped with an auxiliary air valve will guarantee a saving of 20 per cent in fuel consumption when it replaces a carburetor which has no auxiliary air valve.

Q. Why are some carburetors water=jacketed?

A. The conversion of a liquid like gasoline into a vapor is a chemical action which needs heat to complete it. If no heat is supplied, it will be taken from surrounding objects, or else the vaporization will not be completed. This abstraction of heat from the surroundings can be noticed in unjacketed carburetors in the form of frost or snow forming on the outside of the vaporizing chamber. The water-jacketed carburetor has the hot water of the engine system circulated through it to supply the needed heat, and thus assist and complete the vaporizing of the fuel.

Q. Why are some carburetors supplied with hot air?

A. This is done for the same reason. The pre-heated air is supplied to vaporize the fuel, instead of using cold air and supplying heat from other sources. In principle, it is practically the same as the other.

Q. When hot air is supplied, how is this heated?

A. Generally a stove, or a hollow member around the heated exhaust pipe, is connected by metal tubing to the air inlet of the carburetor; in this way all of the air drawn in is forced to pass around the exhaust pipe, which heats it. This is not always the case, some makers using air sucked in from around the heated cylinders. Still others use an exhaust jacket on the carburetor, and draw the cold air supply in around this, so that it is heated.

Q. What difference does the fuel make in this heating method?

A. On the heavier fuels, such as kerosene, alcohol, distillate, and mixtures of these with gasoline, a great quantity of heat is necessary, as these heavier fuels are more difficult to vaporize and are also slower to start vaporizing. This means an extra supply of heat at starting time, and more than the usual supply at all times. It works out, in the direct use of exhaust gases, through a small pipe tapped into the exhaust manifold, thus giving the highest available temperature. This is used through the carburetor jackets, but, in addition, the air supply to vaporize the fuel is heated. Another vaporizer of heavy fuels, which has been quite successful, places heavy metal weights inside the carburetor in the upper part of the vaporizing chamber and then forces the exhaust gases through hollow passages in these. In this way, the weights are heated up, and this heat is transmitted to the gas and air; the size and nature of the metal gives an equable supply of heat, regardless of the exhaust gases.

Q. What is the throttle valve?

A. A valve placed in the pipe between carburetor and cylinders to vary (or throttle) the quantity of mixture flowing to the latter. This is generally connected to the throttle lever on the steering wheel, and to the accelerator pedal. General practice in driving, after the initial stages of learning, is to set the hand throttle at some medium point, and thereafter to vary the speed of the motor by means of the foot.

Q. What is the general form of this throttle valve?

A. The butterfly throttle is used more than any other form, although the piston valve is considerably used. The butterfly is the simplest form possible, consisting of a thin circular disc the size of the interior diameter of the inlet pipe, fastened at the middle to a round shaft which extends across the pipe, and has a lever fastened on the outside extension. When this lever is turned so that the disc lies at right angles to the pipe, the passage will be shut off; when it is turned up parallel to the pipe, the passage will be wide open, for the disc is so thin as to offer practically no resistance to the gases. The piston type of throttle may be arranged so as to rotate or to slide. When it rotates, it is generally constructed with holes in its walls which register with the opening in the pipe, according to its position. When it slides, these holes are generally continuous at one end, this being moved along so as to register with the opening in the pipe. Another type of throttle is the swinging, or flap valve. This is so shaped as to swing from side to side, closing the passage entirely in one position, and leaving it entirely open in another.

Q. What is a Venturi tube?

A. This is the essential principle of the inner member of the Venturi meter, invented for measuring the flow of water. It consists of two cone-shaped tubes diverging in opposite directions, with the proper relation of angles to one another and to the diameter of the smallest point, or meeting point, of the two tubes. The larger angle should be at the bottom, or entering end for the gases; the nozzle, or needle, should be just at or just below the smallest diameter; and the gases should flow through from end to end, that is, air in at one end, gas in at the middle, mixture out at the other end. In the true Venturi tube, the bottom angle is 30 degrees, the top angle 5 degrees.

Q. When more than one nozzle is used, how are they connected?

A. In practically all multiple-nozzle forms, the arrangement is such that the second (and later) nozzles are brought into action by increased demand from the engine, that is, automatically. In one case, a flap valve covers the second nozzle; but, as the suction increases this is drawn up and the nozzle is uncovered; having its own air supply, the nozzle begins to function as soon as it is uncovered, the amount of gas supplied by it depending upon the extent to which it is uncovered by the suction. In another, the first nozzle passes a fixed amount of fuel, as the engine demands rise; this suction is communicated to the second nozzle and the fuel standpipe from which it draws; it is put into action, but varies its supply always according to demand. The combination of fixed and variable nozzles gives reasonably good vaporization at all possible speeds and under all variations of conditions.

Q. What is a horizontal=outlet carburetor?

A. The first carburetors were all connected to the engine cylinders through the intermediary of an inlet manifold. The latter connected up to the cylinder horizontal face at a number of points, and was carried down to a single flange for the carburetor connection. While the surface of this flange was horizontal, the outlet on the carburetor, that is, the passage to this, was vertical. Consequently, carburetors made to fit this arrangement are said to have vertical outlets. With the principle of block casting, it is usual to incorporate the inlet manifold in the cylinder casting and have a single carburetor opening and place for attaching, this being a vertical face. As the face, or carburetor flange, is at right angles to the body of the carburetor outlets, this brought about a horizontal outlet. A carburetor with this form of outlet, and intended to bolt directly upon the cylinder casting in the manner just described, is called a horizontal-outlet carburetor or a horizontal carburetor.

Q. What is a double carburetor?

A. A double carburetor is one made for a V-type of motor in which a common float chamber supplies fuel to two separate and distinct groups of vaporizing chamber, fuel nozzle and needle, air inlet, etc., each half supplying one of the blocks of cylinders. That is to say, it is a double carburetor, or two carburetors, if that is easier to understand, each one of which supplies one-half of the engine's cylinders, but has nothing to do with the other half. It has been found that better results can be obtained in this way than in any other.

Q. What has been the effect of vacuum feeds?

A. The principal effect has been to raise the carburetor. Formerly, the carburetor had to be set low so the fuel could flow to it, and even when pressure became general, the carburetors were still set very low. Now, with auxiliary tank feeding, it is possible to raise the carburetor from two to six inches, and practically all designers have taken advantage of this. It makes the carburetor easier to adjust, easier to prime when priming is necessary, less likely to be stopped or clogged by road dirt or water, because it is farther away from the road and better protected, also, the car can go through deeper water without stopping. Another effect has been to produce a steadier and more even flow of fuel at all times and under all circumstances. In one way, this gave better power, in another, it benefited by giving better economy.

Q. What is the vacuum feed?

A. It is an auxiliary gasoline tank which draws the fuel from the main gasoline tank at the rear of the chassis (or elsewhere). It does this and maintains itself filled automatically, the vacuum being used to raise the fuel from the main tank to the auxiliary, which is usually about a foot higher. The tank can be placed anywhere, but the two usual mountings are on the inside of the bonnet, either on the engine or on the dash.

Q. What other methods are there of fuel supply?

A. The original method was by gravity, from a tank under the front seat. This necessitated having the carburetor so low that the fuel would flow to it on the steepest hill. The substitute for this was pressure, but this necessitated much apparatus, and the system had to be kept air tight, or it was useless. In this form an air pump forced air through a regulator into the air-tight tank, this pressure forcing the fuel out and to the carburetor. The latest device is similar to the vacuum tank but is operated by utilizing the pressure of the exhaust, working through a pressure-regulating valve.

Q. Describe this exhaust=operated system?

A. The exhaust gas pressure is cut down to a few pounds by the regulator, and goes thence into the rear gasoline tank. Here it creates pressure and forces out gasoline which must flow to the auxiliary tank. As the tank fills, a float rises, and with it a needle, which closes a connection to the outside. When the tank is filled to the predetermined level, this arrangement opens the outside connection, and the exhaust gas is free to escape. As the fuel flows to the carburetor, the float drops and, in time, closes this opening, when the exhaust pressure starts the fuel flowing again. So the arrangement of float and outside opening keeps the auxiliary tank continually filled.

Q. When no fuel flows, yet the tank is filled, what is the trouble?

A. If the tank is full and no fuel flows, there must be an obstruction in the line somewhere. Try the gasoline pipe line first for a bend or kink. If none is found, try the carburetor connection. Failing that, remove the strainer and inspect it. Then look into the float and float chamber, float valve and outlet to vaporizing chamber. Some one of these is sure to be at fault.

Q. How can a punctured float be managed, so as to get home?

A. Let the float sink, but oppose this sinking by means of a spring, carefully cut to the right length to give the same effect as if the float were O. K. This will carry the car to the nearest repair shop, or lacking that, will take it home. A punctured metal float can readily be soldered, but should be dried out very carefully first, this being done primarily to make sure there is no more gasoline inside, nor any vapor to condense.

Study Questions for Home Work

1. What are the general rules for adjusting Stromberg carburetors, Models L, LB, M and MB? If an entirely new setting is necessary on Model MB, what is the correct procedure?

2. What is the purpose of the economizer adjustment on the Stromberg Model L?

3. Tell how the main jet is replaced on the Zenith.

4. A car equipped with a Zenith Model O carburetor does not accelerate well and slow speed running is not smooth. What is the trouble? What is the remedy when this car will not develop full speed?

5. Give the method of making a slow-speed adjustment on the Ford car.

6. Describe the construction of the Master carburetor throttle.

7. Explain the action of the air damper on the Master carburetor.

8. How is the Miller carburetor adjusted for altitude?

9. Mention in detail the process of starting adjustment of the Webber.

10. How many adjustments has the Rayfield? Describe them.

11. What is the mixture-indicating pointer on the Newcomb? What are its advantages?

12. How would you adjust a new Schebler Model "L"?

13. What is the predominating feature of the Stewart carburetor?

14. How is the Johnson carburetor adjusted?

15. What are the salient features of the Packard carburetor?

16. Describe the adjustment of the Cadillac, (a) low speed, (b) starting, (c) high speed.

17. Select and describe the working of a heavy fuel carburetor.

18. Describe in detail the workings of the Carter auxiliary tank.

19. It is desired to burn distillate in a truck. What carburetor would you select?

20. What is the difference between an oxygen-adding device and a regular carburetor?

21. Describe the construction of the Bennett air washer and of the Parrett air cleaner. Where are such devices necessary?

22. Describe the construction and operation of the Toquet atomizer.

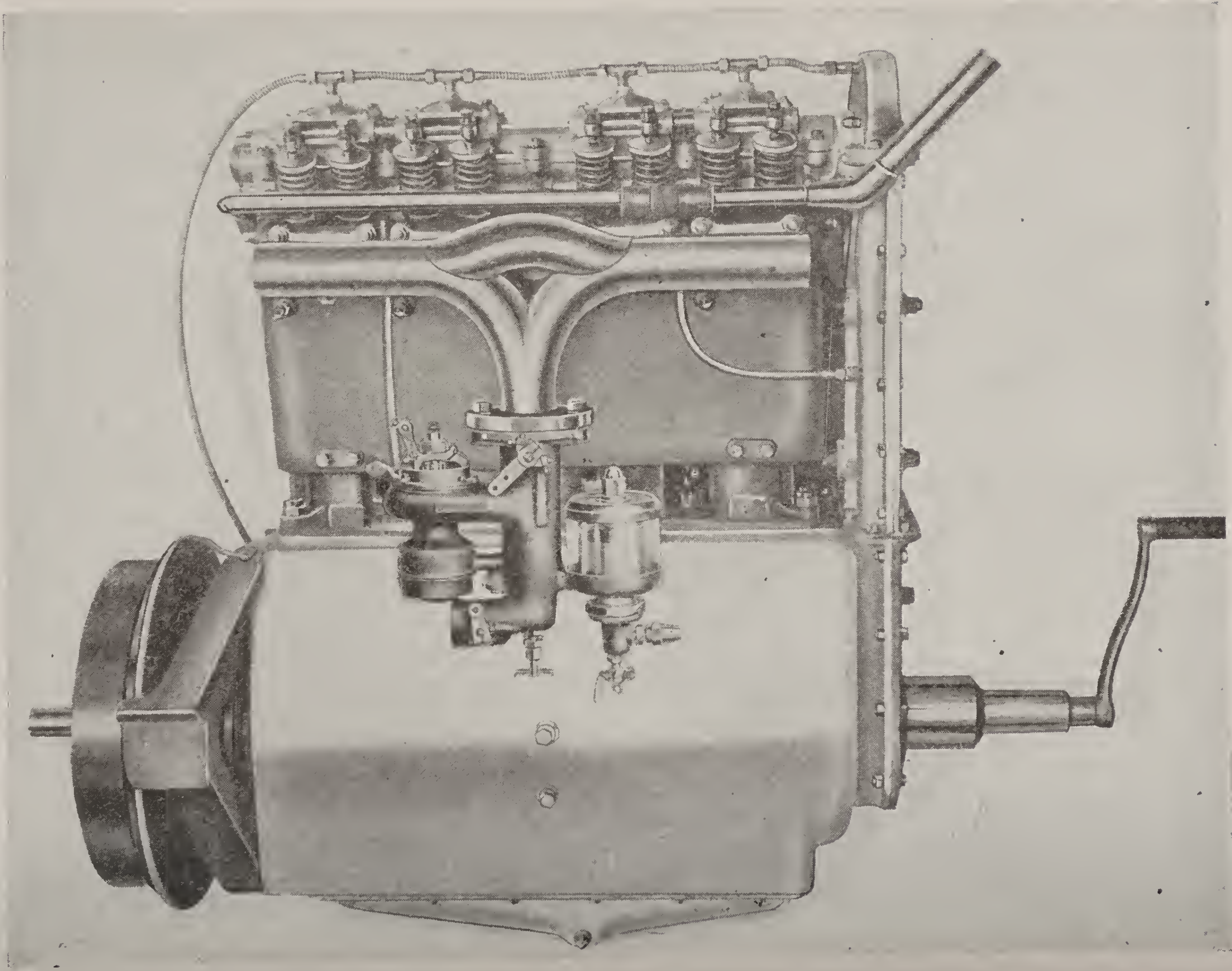
23. Describe the construction and operation of the Ensign fuel converter. How is alcohol used in this instrument?

24. How is vaporization obtained in the "Nitro?" How many adjustments are possible?

25. What is the purpose of the flexible reeds in the Tillotson carburetor? How are they operated?

26. How is a mechanical subdivision of the fuel obtained in the Shakespeare carburetor? How is this carburetor adjusted?

27. Trace the fuel through the Holley "all fuel" carburetor.



WISCONSIN SIXTEEN-VALVE MOTOR BUILT FOR STUTZ MACHINE

GASOLINE AUTOMOBILES

PART III

ENGINE-GROUP ELEMENTS (Continued)

VALVES AND THEIR MECHANISM

Importance of Valves. Probably the most important thing about a four-cycle gasoline engine is the valve, or, more correctly, are the valves, for the usual number is two per cylinder. The opening and closing of these control the functions of the engine; for if the valve does not open and allow a charge of gas to enter, how can the piston compress, and the ignition system fire, a charge? Similarly, if the exhaust valve is not opened and the burned gases allowed to escape, they will mingle with and dilute the fresh, incoming charge, possibly to the extent of making the latter into a non-combustible gas. This is purposely stated in this way because both methods mentioned have been utilized for governing the engine speed, although not to any great extent in automobile work.

Summary of Valve Features. In the valves and valve mechanisms of modern gasoline engines there have been and are impending more interesting changes than seem in prospect in any other portion of the mechanism of the modern automobile. Particularly is this the case with reference to the present tendency to discard the poppet valve with its many objectionable features. Even where there is no tendency toward the use of a sleeve-valve or slide-valve form of motor, much experimenting has been done with increasing the number and changing the position of the valves.

Poppet Valves. Though the very first internal-combustion engines ever made were operated with slide valves, the poppet valve was introduced very early in the history of this art, and has reigned supreme in practically all types of gas and gasoline engines.

The chief advantage of the poppet valve is its capacity for continuous operation at excessively high temperatures, but since the cooling of engines has progressed to the status of high reliability, this advantage is of less importance than formerly. And the disadvantages of poppet valves—the small openings that they afford, the noisy and hammering action they involve, their tendency to leak and in other ways give out, and the necessity for frequently regrinding them—are objections so serious that it is no wonder the prospect of their elimination is so widely welcomed.

About the only recent improvement that has been made in poppet valves is in the quality of material used in them. Many valves now used have cast-iron and nickel heads, which offer a maximum resistance to warping from the heat to which they are subjected. These are fitted with carbon-steel stems, which are superior in their wearing qualities. More use has been made recently of tungsten as a material for valves. Steel containing this is even harder than nickel steel, and experiments have shown that it does not warp as much. In practice, the objection found to cast-iron heads was that the fastenings to the carbon-steel stem were not sufficiently strong to withstand the constant pulling and pushing to which a valve was subjected. As a result they separated, causing trouble.

In the operation of poppet valves, the cams become an important factor. These are the parts which, in revolving, raise the valves so that they open at the proper time. In addition, the cams are so shaped as to hold the valves open for just the right length of time and allow them to close, through the medium of the valve-spring pressure, at the proper point in the cycle. The importance of this can be seen, if we consider that opening the slightest fraction of a second too late will reduce the amount of the charge very much, and thus lessen the power developed by the motor.

Enclosures. The use of casings to enclose the valve stems, springs, and push rods, so as to keep these elements from exposure to dirt, and at the same time silence, in a large degree, the noise they make, is also becoming usual.

Many excellent examples of this may be seen in modern motors. The whole side of the motor where the valve mechanism is located is covered with a long removable plate, keeping in noise and lubricant and keeping out dirt. Usually, however, on a six-cylinder motor the valve enclosure is made in two parts, one half enclosing the mechanism of the valves in the first three cylinders, the other half, those in the last three. This is, of course, the preferred construction on those six-cylinder engines which have the cylinders cast in threes, instead of in a block, as the one referred to. On some motors where this construction has not found favor, the designers have followed the plan of enclosing the individual valve mechanisms. While more expensive, this method is equally as efficient. On the other hand, it adds to the parts, and the whole modern tendency has been to reduce the number of parts.

Sleeve Valves. This type of valve, while not at all new, has only within the past few years come into considerable prominence, chiefly as a result of the truly remarkable performances of the Knight motor, which is equipped with the most advanced examples of this type of valve.

Contrary to past opinion, it has been conclusively demonstrated that sleeve valves do not, to any perceptible degree, increase the tendency of a motor to overheat, nor do they wear at any very measurable rate. They afford, moreover, in the best constructions, a much higher thermal and mechanical efficiency than it is possible to secure from the average poppet-valve motor, this improvement being due to the better-shaped combustion chamber that can be used and the greater areas of valve opening, which facilitate the ingress and egress of the charges.

Another advantage in favor of the sleeve valve is that its timing is permanent and unchangeable and does not alter materially with wear. Not the least of the merits of the sleeve valve is found in the fact that it lends itself to positive operation by eccentric mechanisms, which are in every way greatly superior to the non-positive cam mechanisms universally used to actuate poppet valves.

A very good example of this latest type of Knight motor is illustrated in Fig. 149, showing the intake side of the Moline-Knight four-cylinder motor.

Sliding Valves. Sliding valves of other than the sleeve type, embracing a considerable variety of piston valves and valves similar to those employed in steam engines, have not found as much favor with designers of automobile engines as have other types herein referred to.

One exception is the successful use of a "split-ring" valve sliding up and down in the cylinder head just above the piston, which has found successful application in a few motors recently built by the Renault Company, of France.

Rotating Valves. A number of engines with rotating valves have been built from time to time, but none of these seem to have survived the test of time, for not one which was in evidence two years ago is being made now. A case in point is the Speedwell car with the Mead rotating-valve motor. The motor was excellent but is no longer made.

Half-Time Shafts. For the actuation of the valve mechanism of any four-cycle motor, it is necessary to have a shaft (or in the case of rotary valves, to run the valve itself as a shaft) turning at one-half the speed of the crankshaft through a two-to-one gear ratio.

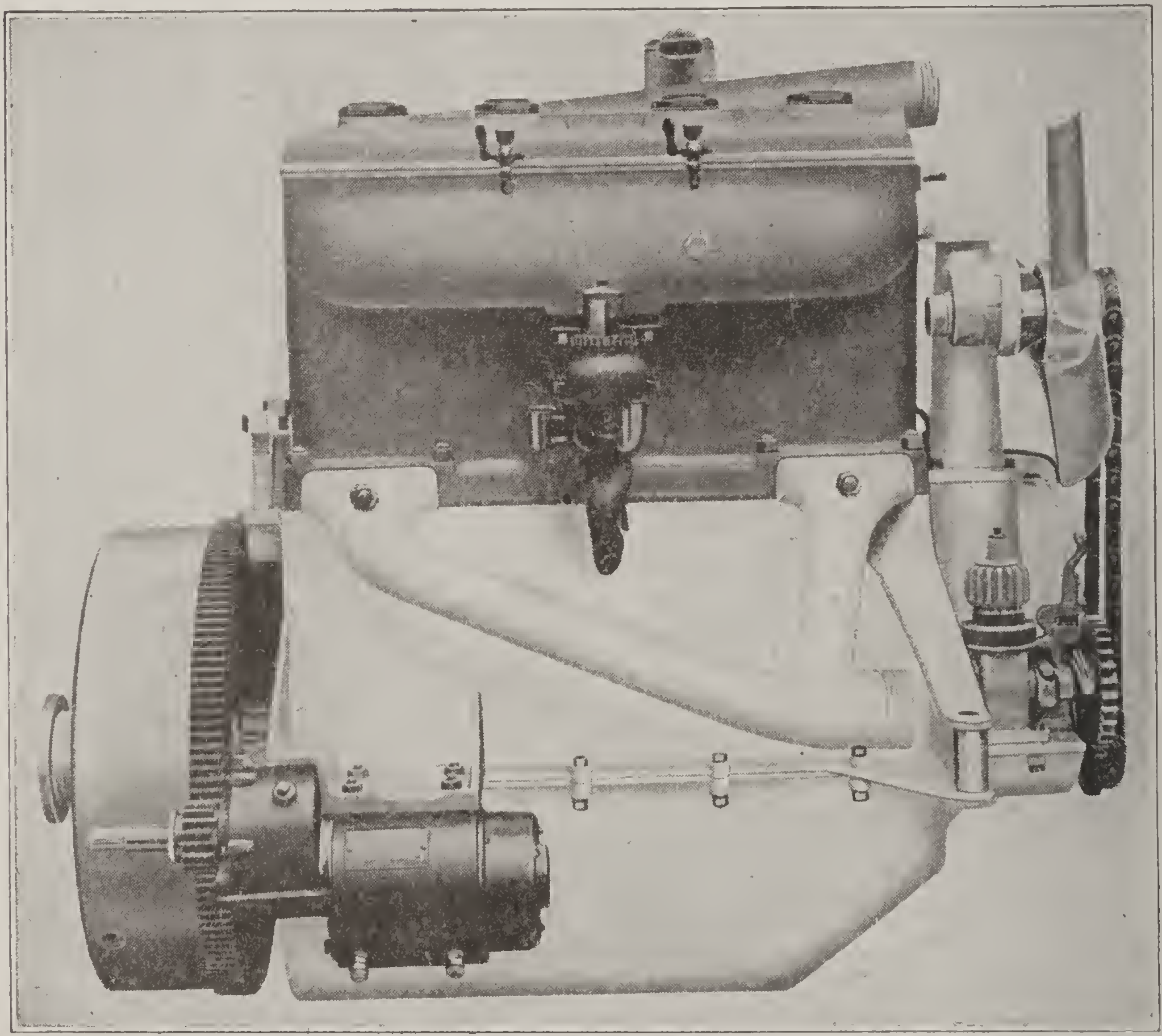


Fig. 149. Intake Side of Moline-Knight 50-Horsepower Motor
Courtesy of Moline Automobile Company, East Moline, Illinois

Ordinarily the half-time shaft is the camshaft, but in motors of the Knight type it is, of course, an eccentric shaft. Camshafts, particularly, call for good workmanship and high-grade materials, as well as sound design, since the constant pounding of the valve stems or push rods on the cams is a prolific source of trouble, if anything but the soundest of sound construction be employed.

The most important recent innovation in this detail of automobile mechanism is the driving of half-time shafts by silent chains in place of the long-used gearing of spur and helical type. By this improvement the noise of the gears is eliminated.

A typical silent-chain installation, driving half-time shaft and other shafts as well, is seen in Fig. 150, which presents the King eight-cylinder motor with the chain cover removed. These occupy the compartment formerly called the gear case, or gear cover, when all driving was done by gears. Here it will be noted that there are two sprockets on the crankshaft; one driving the camshaft through the medium of a third sprocket which serves a double purpose, as a chain

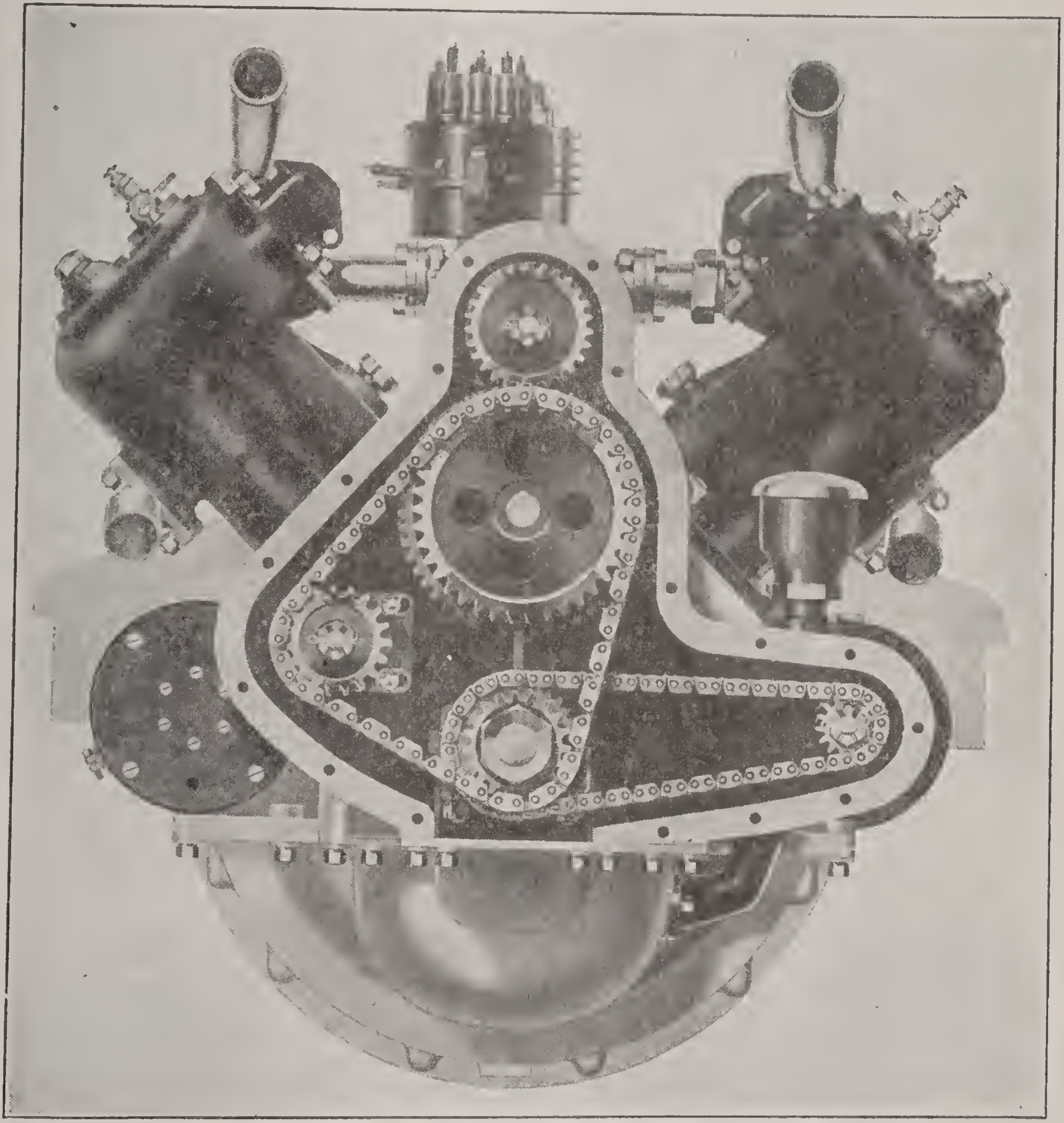


Fig. 150. Front of King Eight with Cover Removed to Show Use of Silent Chain
Courtesy of King Motor Car Company, Detroit, Michigan

tightener and as a drive for the pressure oil pump; while the other sprocket, through a second silent chain, drives the electric generator at the right, no tightener being needed as the generator can be moved sufficiently to care for this.

In the Cadillac motor, shown in Fig. 2, Part I, a pair of gears is used, one driving the camshaft from the crankshaft, while the other drives the auxiliary shaft from the camshaft. In the American form of Knight sliding sleeve-valve motors, shown in Fig. 149, a pair of silent chains is used for the eccentric shaft on one side and the electric generator on the other. These are driven from a pair of sprockets set side by side on an extension of the crankshaft.

A point that should be brought out in connection with silent-chain camshaft driving is that the use of the chain allows the shafts to be placed anywhere desired and thus, to a certain extent, frees the designer from the former restriction of a two-to-one reduction ratio in the gears, which rather fixed the size and, consequently, the position of the gears. This restriction had an influence also upon cylinder design, as the center of the camshaft fixed the center of all the valves, that is, their distance from the center line of the motor.

DETAILS OF POPPET=VALVE GEARS

Cams

Friction. Granting the necessity for proper means to regulate the inflow and outgo of the charge and consequent products of combustion, as exemplified by the valves, the next most important part is the one which controls the movement of the valve, and is, therefore, essential to the success of the latter. This is what is known as a cam and in the usual case amounts to an extension of, or projection from, the so-called camshaft. In as much as the valve functions only come into play upon every other stroke of the crankshaft, this camshaft is gear-driven from the crankshaft, so as to rotate at half the speed of the latter. This is very simply effected by having the cam gear twice as large as the crankshaft gear. As the same valve is never used for both the inlet and the exhaust, so the cams are seldom made to do more than the one thing, namely, operate one set of the valves. From this has grown the custom of referring to them according to the function of the valve which they operate—inlet cam, exhaust cam, etc.

TABLE I *

Timing Regulation of a Number of Prominent French Motors

Nos.		Lead of Exhaust Opening	Lag of Inlet Closing	Ignit. Advance	Lag of Exh. Closing.	Lag of Inlet Opening	Relation of Conn. Rod to Radius Crank	R.p.m. at Full Power
1	Ours	55°	20°	var.	0°	15°	4.76	1 000
2	Charron—20/30 h.p., 1908	44°	0°	—	0°	1°	4.55	1 100
3	Rossel—40 h.p., 4 cylinders	38°	23°	—	0°	2°	4.29	1 100
4	Gregoire—10/14 h.p., 4 cylinders, 1908	53°	0°	—	0°	5°	4.18	1 200
5	Motobloc—24 h.p., 100/120, 1908	45°	10°	—	5°	10°	4.75	1 200
6	Panhard-Levassor	45°	40°	—	0°	0°	4.5	1 200
7	Hotchkiss—4 cylinders, 95/100	44°	33°	—	10°	17°	4.27	1 300
8	Cottin-Desgouttes—18/22 h.p.	46°	30°	38°	8°	15°	4.15	1 300
9	Brouhot—12 h.p., 4 cylinders, 75/110	45°	45°	30°	0°	20°	5	1 300
10	Cornilleau - Ste. - Beuve — 20/30 h.p., 1908	56°	20°	43°	6°	20°	4.62	1 300
11	Mutel—40 h.p., 1908	62°	21°	var.	28°	26°	4.4	1 300
12	Berliet—22 h.p., 1908	48°	38°	—	9°	17°	4.5	1 300
13	Peugeot (*Paris*)—18/24 h.p., 1908	58°	18°	38°	0°	10°	4.76	1 300
14	Labor—20/30 h.p.	51°20′	0°	var.	0°	0°	4.18	......
15	Luc Court	45°	0°	—	15°	30°	4.25	......
16	Brasier	45°	25°	34°	0°	7°	4.5	1 350
17	Peugeot (*Beaulieu*)	51°30′	58°	31°	20°	15°	4.78	1 400
18	Aster—9 h.p., 105/120	40°	40°	var.	0°	0°	4.3	1 400
19	Rochet-Schneider—24 h.p., 100/-120	40°	20°	20°	0°	20°	4.75	1 400
20	De Dion-Bouton—12 h.p., 4 cylinders, 1908	45°	45°	30°	0°	0°	4.7	1 400
21	Eudelin	36°	20°	var.	4°	8°	4.3	1 450
22	Farcot—14 h.p., 80/100	36°	10°	—	2°	6°	4	1 500
23	Chenard-Walcker	36°	36°	—	0°	0°	5.25	1 500
24	Darracq—10/12 h.p., 100/120	48°	30°	21°	0°	0°	4.5	1 500
25	Aries—14/18 h.p.	58°	44°	20°	13°	18°	4.91	1 500
26	Vinot-Deguingand — 12/16 h.p., 80/110	30°	15°	27°	0°	15°	4.54	1 500
27	Sultan—9/12 h.p., 4 cylinders, 75/110	58°	42°	32°	14°	22°	4.55	1 600
28	Renault—8 h.p., 2 cylinders	32°	26°	33°30′	10°	23°30′	4.33	1 600
29	Unic—20 h.p., 75/110	53°	40°	30°	10°	34°	4.5	1 650
30	Sizaire et Naudin—15 h.p., 120/-110	44°	37°	var.	0°	15°	5.25	1 700
31	Larrad Device	52°	17°	—	22°	17°	.....	.....
	Average	46°20′	26°15′	—	5°40′	8°6′	.....	.....

* The motors are arranged in the order of their increasing speeds. The angles are figured in degrees, counting from the nearest dead center. "Var." means that the point of ignition may be advanced or retarded by the driver.

In laying out or designing a set of cams for a gasoline engine, such as is used on an automobile, it is first necessary to decide upon the exact cycle upon which to operate the engine. By this is meant the exact length of time, as referred to the stroke, in which the valve action will take place. Upon this subject, designers all over the world differ, and no wonder, as this cycle can but be judged by results, for it is impossible to watch it as it transpires. Deductions differ, therefore, as to what happens and, consequently, as to the effect of various angles of beginning and ending of the valve actions.

TABLE II

Timing Regulation on a Number of Prominent American Motors

Nos.		Lag of Inlet Opening	Lag of Inlet Closing	Lead of Exhaust Opening	Lag of Exhaust Closing
1	Abbott 34–40	11° 30′	44° 12′	45° 48′	11° 30′
2	Abbott 44/50	17° 53′	29° 25′	42° 36′	8° 20′
3	Abbott Belle Isle	10° 00′	20° 00′	40° 00′	2° 30′
4	Allen 40	15° 00′	40° 00′	45° 00′	10° 00′
5	Cadillac 1914	14° 20′	38° 26′	31° 34′	17° 00′*
6	Cameron 1914	5° 00′	20° 00′	50° 00′	10° 00′
7	Corbitt D, E, and F	11° 00′	35° 00′	45° 00′	3° 00′
8	Chalmers	12° 00′	33° 00′	55° 00′	12° 00′
9	Crescent	20° 00′	45° 00′	55° 00′	15° 00′
10	Chandler Six	14° 00′	39° 00′	49° 30′	12° 00′
11	Crane 4	.. ..	35° 00′	50° 00′	10° 00′
12	Correja	10° 00′	35° 00′	44° 00′	5° 00′
13	Chevrolet C	13° 00′	49° 00′	47° 00′	9° 00′
14	Case 40	13° 00′	30° 00′	50° 00′	13° 00′
15	Cunningham	15° 00′	15° 00′	40° 00′	12° 00′
16	De Soto Six	10° 00′	25° 00′	38° 00′	8° 00′
17	Franklin V–4	8° 00′	33° 00′	51° 30′	17° 00′
18	Great Southern	14° 00′	25° 00′	35° 00′	10° 00′
19	Haynes, 26, 27, and 28	5° 00′	35° 00′	47° 00′	2° 00′†
20	Howard 6–D	10° 00′	28° 00′	40° 00′	2° 30′
21	Hupmobile 32	21° 00′	28° 00′	46° 00′	16° 00′
22	Jackson Olympic, Majestic, and Sultanic	15° 00′	38° 00′	45° 00′	10° 00′
23	Jeffery 6–96 and 4–93	18° 00′	46° 00′	47° 00′	15° 00′
24	King B	9° 44′	30° 38′	32° 10′	5° 00′
25	Krit M	12° 00′	28° 00′	39° 00′	2° 00′
26	Lewis Six	15° 00′	30° 00′	45° 00′	5° 00′
27	Locomobile R3 and M4	Dead Center	46° 22′	50° 52′	16° 27′
28	McFarlan 6–T	10° 00′	36° 00′	43° 30′	10° 00′
29	Maxwell 4–35	5° 00′	40° 00′	35° 00′	Dead Center
30	Maxwell 4–25	6° 00′	32° 00′	43° 00′	6° 00′
31	Moon Six 50	10° 00′	28° 00′	40° 00′	2° 30′
32	Moon Four 42	14° 00′	24° 00′	31° 00′	21° 00′
33	Marathon Winner, Runner, Champion	12° 00′	45° 00′	46° 00′	7° 00′
34	Moyer E and G	8° 00′	40° 00′	45° 00′	10° 00′
35	Norwalk 6–C and 6–D	6° 00′	40° 00′	45° 00′	5° 00′‡
36	Oldsmobile 54	15° 00′	38° 00′	45° 00′	10° 00′
37	Paige 25	9° 40′	32° 25′	40° 30′	12° 00′
38	Paige 36	9° 40′	32° 30′	41° 50′	11° 40′
39	Palmer-Singer Brighton Six L	6° 00′	40° 00′	45° 00′	5° 00′
40	Paterson 32 and 33	15° 00′	38° 00′	45° 00′	10° 00′
41	Pathfinder 4	11° 30′	44° 12′	45° 48′	11° 30′
42	Pathfinder Big and Little Six	10° 00′	28° 00′	40° 00′	2° 30′
43	Pratt 50	12° 00′	45° 00′	45° 00′	10° 00′
44	Reo the 12th	18° 00′	36° 00′	53° 30′	14° 00′
45	Republic E	15° 00′	30° 00′	45° 00′	10° 00′
46	S. & M	10° 00′	28° 00′	40° 00′	2° 30′
47	Selden 49	13° 00′	26° 30′	48° 30′	7° 30′
48	Simplex 50	13° 10′	34° 40′	57° 30′	15° 40′
49	Simplex 38	10° 20′	31° 40′	54° 20′	7° 50′
50	Spaulding T	5° 00′	45° 00′	55° 00′	5° 00′
51	Speedwell ABC	10° 00′	28° 00′	40° 00′	2° 30′
52	Touraine 12	3° 00′	40° 00′	43° 00′	3° 00′
53	Velie 9–45, 6–40, 9–5, 9–4, 9–2, 6–5, and 6–4	7° 00′	36° 00′	43° 00′	12° 00′
54	Velie 11–35	5° 00′	31° 00′	39° 00′	13° 00′
55	Vulcan	15° 00′	30° 00′	45° 00′	10° 00′
56	Zimmerman B–6	10° 00′	25° 00′	38° 00′	8° 00′
	Average	10° 48′	35° 7′	50° 10′	9° 20′

* Some Cadillacs have the inlet opening at 4° 20′ past the top center and the exhaust closing 7° 00′ past.

† The Haynes 28 has the exhaust opening 37° 00′ before the lower center instead of 47° 00′.

‡ Norwalk 6-D has the inlet opening at 8° 00′ instead of 6° 00′, and the exhaust closing on the upper dead center instead of at 5° 00′ past.

Tables of Valve Settings. Table I, showing the valve settings used by the foremost French car designers, is here given as a basis of comparison with the valve data of American types, Table II. The valve timing for American cars as produced in 1913 and 1914 is given in Table II, while Table I was compiled in 1908; a comparison which indicates in a measure the advance in the past five or six years. In studying these tables, it should be borne in mind that all angles are spoken of in terms of the crankshaft and are usually referred to the two dead centers, commonly spoken of as the upper dead center and the lower dead center.

In Tables I and II, it will be noted that in so far as maximum openings were concerned there has been little change. The earliest exhaust opening of 1908 was Mutel at 62°; the earliest American exhaust opening of the present is Simplex 50 at 57° 30′. The former closed at 28°, while the latter closed at 15° 40′, thus giving the French motor a total exhaust opening of 270°, while the American has but 253° 10′. Simplex is not a representative American car, however; it is a special model with racing characteristics, and is built only to order. Crescent and Reo are the real leaders.

With reference to inlet valves, the situation is somewhat similar, the largest foreign lag in opening is the Unic with 34°; while the largest American opening lag is the Hupmobile with 21°. In closing, the highest figure reached by the foreign product is 58° by Peugeot, and on this side, 49° by Chevrolet. The former shows also the greatest total, 254°; but the largest American total is that of Crescent with 205°.

These, however, represent the extreme cases, and the averages tell a different story. The average foreign inlet opening (total) in 1908 was 232°, while the average American inlet opening is now 239.3°. Similarly, with the exhaust total opening, the average foreign figure then was 214.5°, the average American figure is now 226.2°.

It is unfortunate that the speed at full power output of the American motors is not available also, as that would allow an even more interesting comparison of the two tables. In Table I, it will be noted that the motors are arranged in the order of their maximum speeds. Were the American speed figures available, it would show for one thing whether speeds of today are, as claimed, so much higher than formerly and also, what is more to the point, what valve setting gives the highest speed. Referring to Table I, it will be seen that Unic with the greatest lag of inlet opening and the greatest total inlet opening is next to the highest in speed, whereas the others having high lag figures are all down among the moderate speeds.

Now, if the average of the numerous examples of good practice be taken, it is not a hard matter to explain the form of the cam and its derivation. The height of the upper surface of the highest part of the cam above the surface upon which the valve-actuating device normally rests determines the lift of the valve, which is the name given to the amount it is opened or lifted. This is not really the lift of the valve because of the fact that in all valve-operating systems there is a certain amount of clearance between the lower end of the valve stem and the upper end of the valve lifter mechanism. This clearance must be taken up by the cam before the valve itself is actually lifted, so, to obtain the true lift, the amount of the clearance is subtracted from the lift as determined by the cam height. Knowing this, designers usually predetermine the clearance and allow for it in the height of the cams.

Typical Valve Actions. Figs. 151 and 152 illustrate the complete valve action very well; the former, that of the Locomobile Company of America, Bridgeport, Connecticut, showing the form in which the cam works against a roller in the bottom of the push rod. This works upward in the push-rod guide and has a dirt excluding arrangement at the top. The top of the push rod bears against the bottom of the valve stem with an adjustable hardened screw forming the contact. The valve is held down on its seat in the cylinder by means of a strong spring, which the upward movement of the push rod opposes. The valve is guided in and has its bearing in the valve guide, which is made long to give large bearing surface. As the Locomobile motor is of the **T**-head type, the exhaust and inlet valves are on opposite sides of the cylinders and are operated by separate camshafts. The valve mechanism is completely enclosed.

The second figure shows the valve action used on Haynes cars, made by the Haynes Automobile Company, Kokomo, Indiana. The difference is in the elimination of the roller at the bottom of the push rod which forms the point of contact with the cam. In this form, a flat hardened surface makes the push rod more simple and reduces the number of parts. It has been said against this form that the cam scrapes across the push-rod face and thus wears it, but in actual use it has been found that the push rod rotates and in this way the wear is distributed over the whole flat face, which in this construction can be made much larger than can the face of the roller. The push rods are of the "mushroom" type and are made of nickel steel. The push-rod adjustments are completely enclosed but may be readily reached without disturbing any other unit. They may be removed and replaced without removing the valve springs or valves.

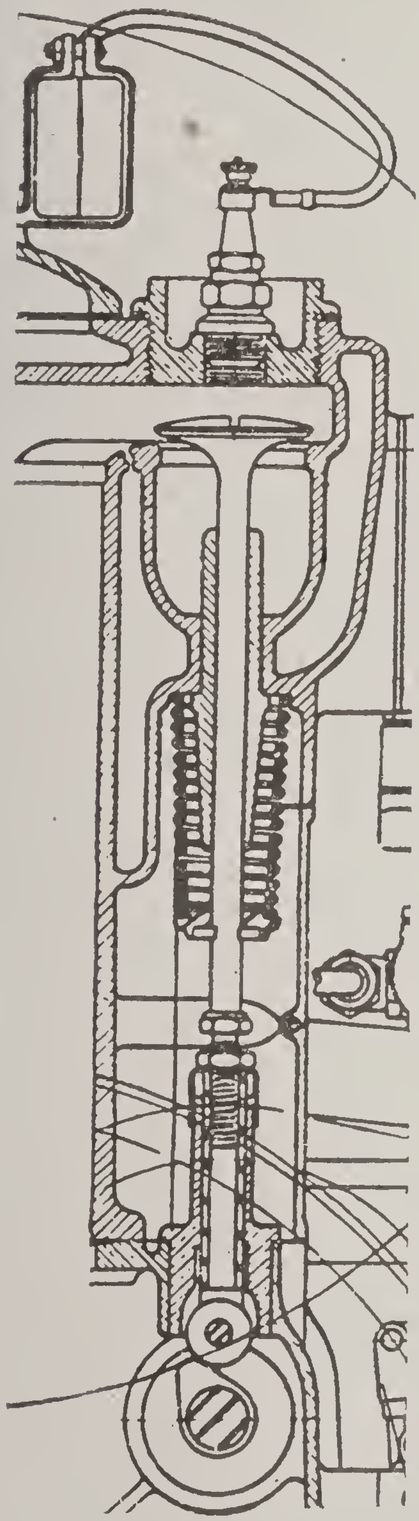


Fig. 151. Complete Valve Motion with Roller Push Rod
Courtesy of Locomobile Company of America, Bridgeport, Connecticut

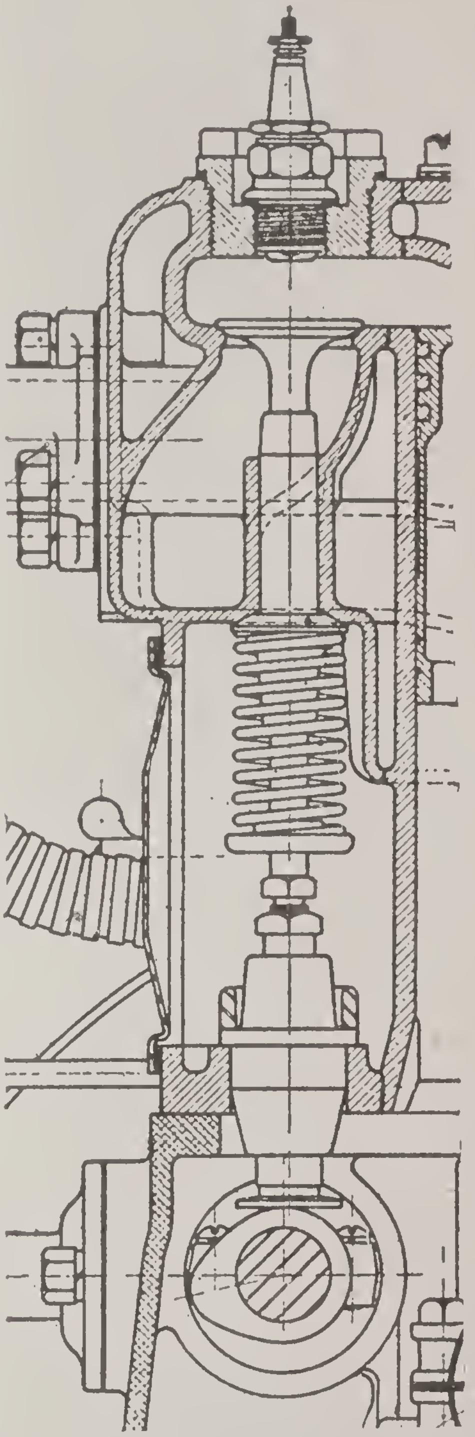


Fig. 152. Complete Valve Motion without Roller in Push Rod
Courtesy of Haynes Automobile Company, Kokomo, Indiana

Neither of these systems is in decided favor, designers being about equally divided between them.

The construction and operation of the cam mechanism is the same whether used in connection with an exhaust or an inlet valve; as the same line of reasoning and the same method of procedure, in both cases, would lead to the same results.

It has many times been tried and still more often urged that the straight surface of the side of the cam is not conducive to the best results, because of the fact that when the first straight portion of the cam surface strikes the cam roller it does so with so much force that it tends to wear the latter in that direction. As for the receding face, it has been urged that the ordinary closing of the valve is too slow and that the straight surface can be altered so as to allow of speeding up the downward movement of the valve. This idea works out into a curve; the back of the surface is hollowed out so that as soon as the cam roller passes the center it drops vertically, owing to the tension of the spring. This method has been tried, but without success.

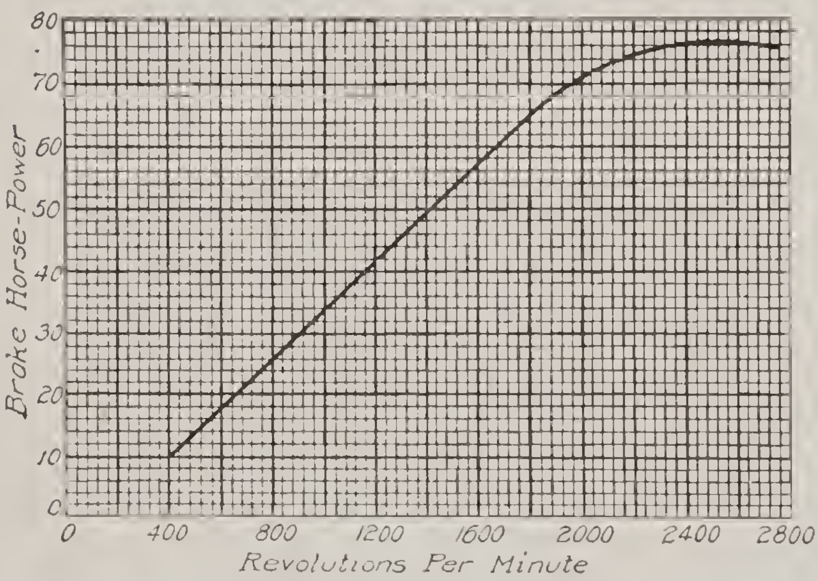


Fig. 153. Power Curve of an American Engine with Superior Cams and Balancing

What Good Modern Practice Shows. A more modern way, which is fast becoming universal, is to use straight sides for the cams and take advantage of rapid closing in another way, the benefits of which more than offset the benefits of the old way and have no corresponding disadvantages. In the ordinary automobile engine running at 1000 revolutions per minute, the gases are traveling into the cylinder at the rate of 5000 to 6000 feet per minute, and traveling out at from 7000 to 10,000 feet per minute. At this tremendous speed, the gas inertia is very high, and experiments go to show that the gases by means of this inertia will continue to force their way into the cylinder even against the return motion of the piston. So it is now common practice to hold the inlet valve open about 30 degrees on the upstroke of the piston, which results in a much larger piston charge. The same practice is carried out with the exhaust, but as the pressure is higher, so large an angle is not necessary. These actions take place on the back—flat side—of the cam surface and have given to the high-speed automobile engine a larger charge and a more complete scavenging effect, resulting in more power and speed from the same size of cylinder.

As proof of this statement, the power curve of an engine of but 3½-inch diameter of cylinder is shown in Fig. 153. This size of six-cylinder engine would be rated by any formula at about 29 horsepower at the maximum speed, and a commercially obtainable type in this size would doubtless be guaranteed to deliver between 20 and 25 horsepower. This engine, which is not built for racing purposes, displays a power curve which continuously rises; a speed at which it would turn downward has not been obtainable in the tests. This curve shows also that the maximum power obtained was over 80, which is nearly three times the power of the ordinary engine of this same size. This result is ascribable to superior valves and superior attention to the valve angles as governed by the cams.

Number of Valves per Cylinder. *Three Valves per Cylinder.* When it was stated that but two valves per cylinder were ordinarily used, with one cam for each, the majority case was spoken of. But, as it is a fact that there are other cases which differ from this, it would not be fair to close the subject without mentioning them. The most prominent advocate of air cooling in this country and the world, the H. H. Franklin Manufacturing Company, used three valves, and consequently three cams, per cylinder. These three were the ordinary inlet; the usual exhaust; and the additional auxiliary exhaust. By re-designing later, this complication was avoided and the third valve eliminated.

The Wisconsin Motor Company has developed another motor with four valves per cylinder and, after a notable racing success, has placed it upon the market. Any maker desiring to do so, may purchase this and incorporate it in his chassis. This emphasizes the distance which the sixteen-valve four-cylinder motor has progressed in the space of a year or so. A section through this motor, both side elevation and end view, showing all the details of the construction, is shown in Fig. 154. A full view of the intake side is given in Fig. 155.

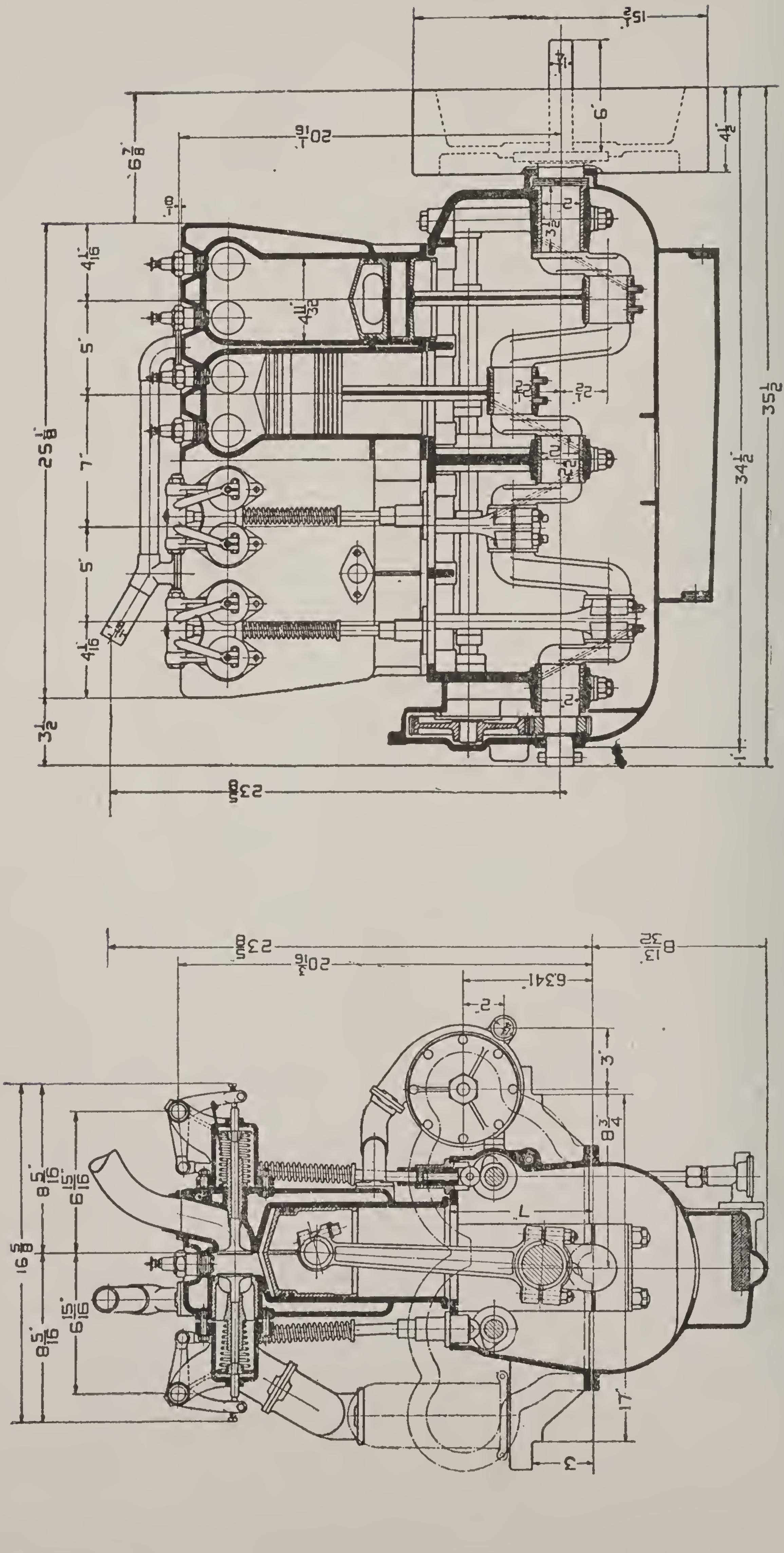


Fig. 154. Sections through Wisconsin Sixteen-Valve Motor—Side and End Views
Courtesy of Wisconsin Motor Company, Milwaukee, Wisconsin

Four Valves per Cylinder. The very latest practice in the way of multiple valves is the use of four valves per cylinder—two inlets and two exhausts. There are a number of reasons why this construction is a good one. It is said that the area through which the gases enter and leave the cylinder can be made greater, thus giving the same or greater supply of gas more quickly and, after using it, ejecting it with the same or a greater volume more quickly. The volumetric efficiency of the cylinder is greatly increased in this way, giving more power and speed from the same size of cylinders, so much more, it is claimed, as to make a four-cylinder engine with sixteen valves the equal of a six-cylinder with but twelve valves. Another big advantage claimed for the smaller lighter valves of this construction is that very much lighter valve springs can be used. This advantage was discovered by using sixteen valves on four-cylinder racing engine where the compression

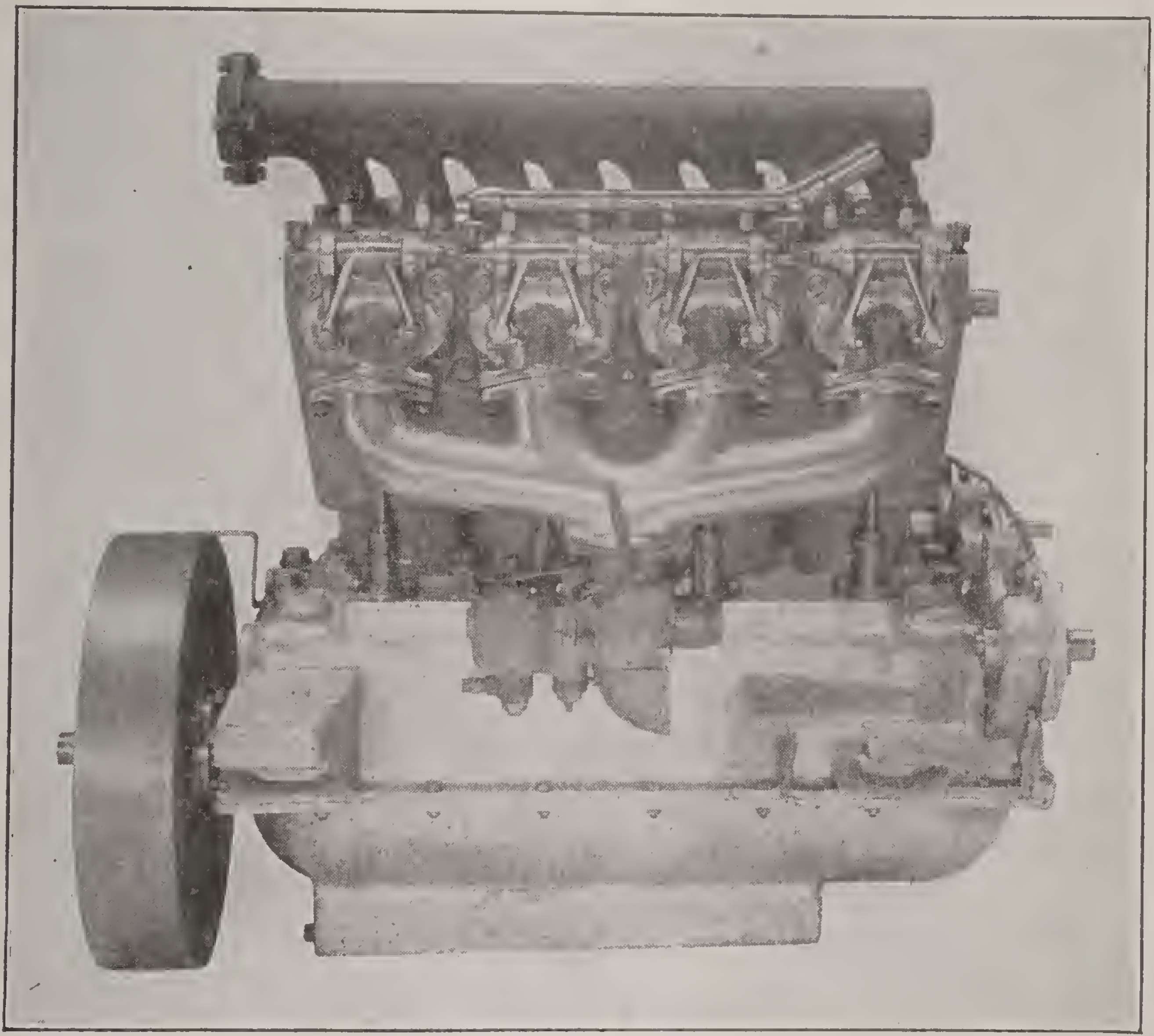


Fig. 155. View of Intake Side of Sixteen-Valve Motor
Courtesy of Wisconsin Motor Company, Milwaukee, Wisconsin

and other pressures were enormous. The valve springs for the ordinary eight-valve engine had to be very stiff and, consequently, gave much cam trouble. The stiff springs dug out the sides of the cams very rapidly and also failed rapidly themselves. With the lighter springs which can be used with sixteen valves, these troubles are eliminated.

In the 39 cars starting in the last French Grand Prix, all but three were four-cylinder forms. Of these 36, two had sleeve valves and three had the usual number of valves, but the other 31 all had sixteen overhead valves. These were about equally divided in respect to camshafts, 17 having but one, 14 having two. In the recently developed Stutz motor, made by the Wisconsin Motor Company, the engine has the outward appearance of any other T-head form, for the use of double the usual number of valves does not change the exterior at all.

One Cam per Two Valves Influences the Shape. A case in which the cam does differ is that of the use of two overhead valves operated by a single camshaft, Fig. 156. This practice originated with the F. I. A. T. Company, which brought it out for racing use only, where it was particularly useful in that it halved the weight of the camshaft, as well as saved much weight in push rods, etc. Later, this was taken up by other firms for regular use, although the company which first brought it out has never done so.

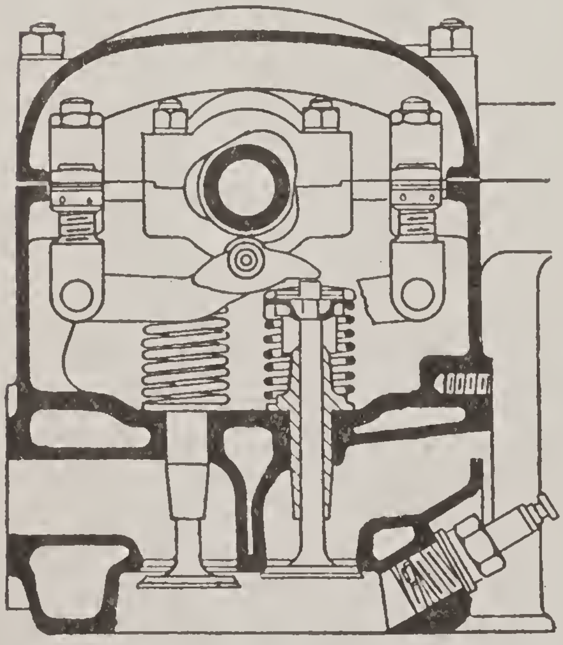


Fig. 156. Overhead Valve Motion with Followers Working Directly on Valve Stems and Having no Push Rods
Courtesy of Chalmers Motor Company, Detroit, Michigan

In this country it has been tried by many makers. The work of opening the extra valve is done by a spring, i.e., a depression in the back of the cam allows a strong spring to pull the push rod down, by which process the valve stem is depressed and the valve opened.

The V-type of motor has made considerable difference in valve motions; for one thing, bringing into use valves set at an angle with the vertical, a practice previously considered very bad because the weight of the valve adds to the tendency to wear the valve and seat on the low side. In the form shown in Fig. 157, the eight-cylinder motor used in the Briscoe 38, made by the Briscoe Motor Company, Jackson, Michigan, there are no unusual features. The single camshaft with 16 cams is centrally placed in the middle of the V and operates the push rods, inclined outward, parallel to their respective groups of cylinders. A rocker arm, or follower, is used at the cylinder heads to transfer this up-and-down motion to the valves which are set in the center of the cylinder heads and are thus parallel to the push rods.

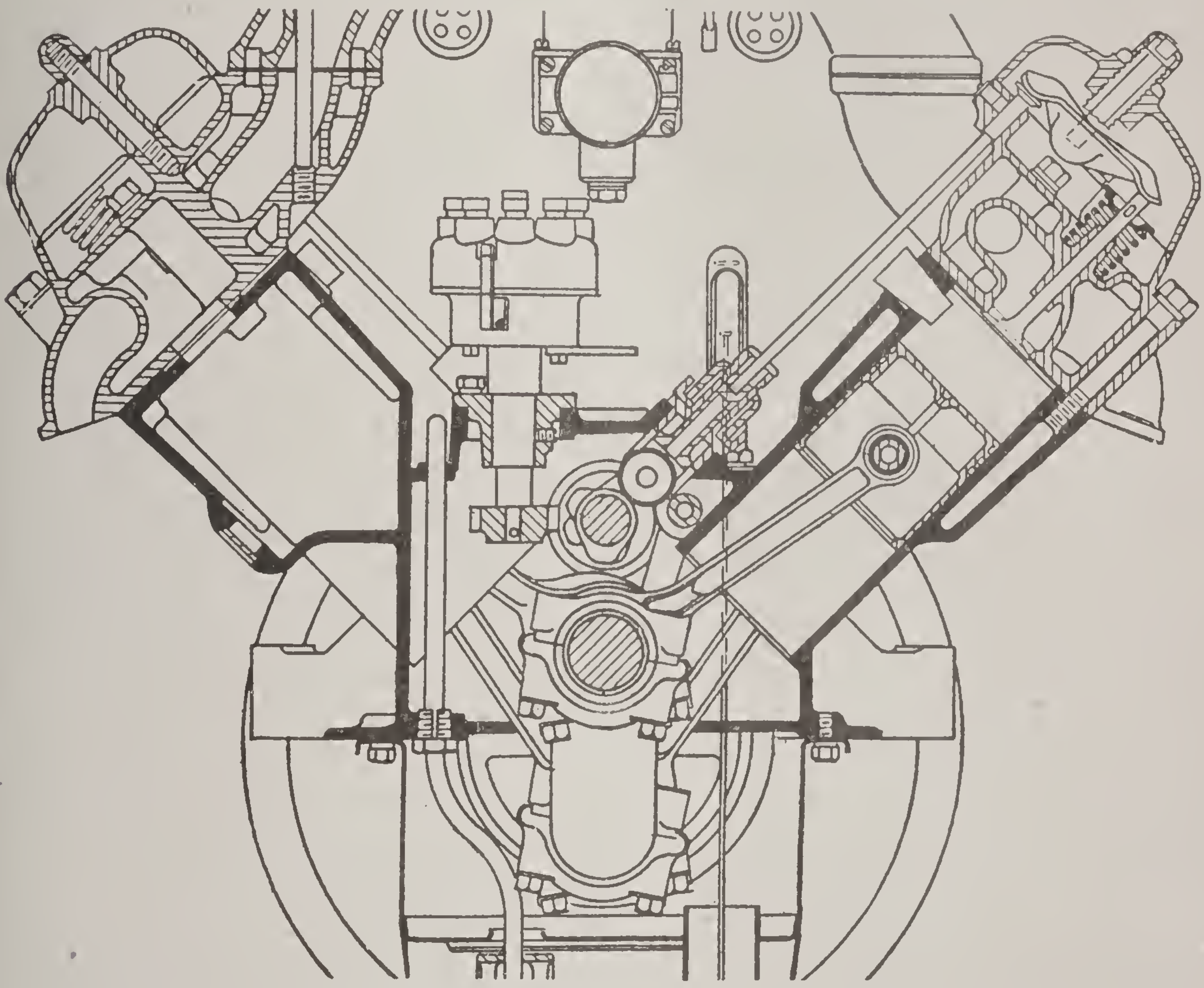


Fig. 157. Section through Briscoe Eight, Showing Camshaft Arrangement

In the majority of V-type motors, both eights and twelves, the valves are in side pockets; the cylinders are of the L-type, and thus there is no radical innovation except the inclined push rods and valve systems. In a few of these motors, however, a follower is used between the cams and the push rods because of other structural reasons.

When any kind of a cam follower differing from the usual direct-lift push rod is used, this may or may not affect the shape of the cam. Usually it does not, so that the shape does not have to be taken into account. Ordinarily these followers are used to prevent side thrust on the push-rod guide, the follower itself taking all the thrust and being so designed as to be readily removable or adjustable, to take care of this. In cases where this does not obtain, the object usually sought is the removal of noise. The two objects may be combined, as in the case shown in Fig. 158. This represents an enlarged view of the cam mechanism of the famous one-cylinder French car, Peugeot. It will be clear that the action is that of one cam operating both the exhaust and the inlet valves through the medium of a pair of levers, upon which the cam works alternately.

A cam follower of somewhat different form, but one achieving the same results, will be noted in the Cadillac eight-cylinder motor, shown in Fig. 164, where attention has been called to these, and also in the Chalmers six-cylinder motor with overhead valves, shown in Fig. 156.

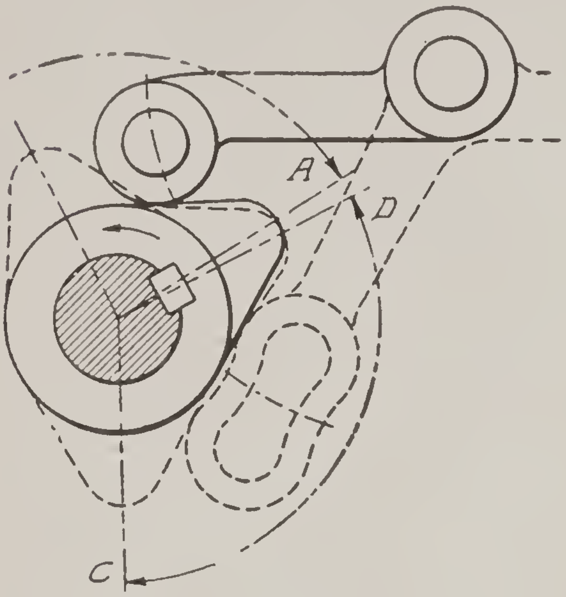


Fig. 158. Cam Mechanism of Peugeot Single-Cylinder Engine

Difficulties in Making Cams. There was a time when the production of a good, accurate camshaft was a big job in any machine shop, well-equipped or otherwise, and represented the expenditure of much money in jigs, tools, and fixtures. Now, however, the machine-tool builder has come to the rescue of the automobile manufacturer, and special tools have made the work easy. So it was with the production of the shaft with integral cams; this used to be a big undertaking, but today special machinery has made it an easy matter. The illustrations, Figs. 159 and 160, show some of the product of a cam milling machine. This is now the favored way of putting out engines, for the integral cams and shaft have the advantage of much lower first cost and, with proper hardening, will last fully as long as those made by mounting the separate cams directly on the shaft.

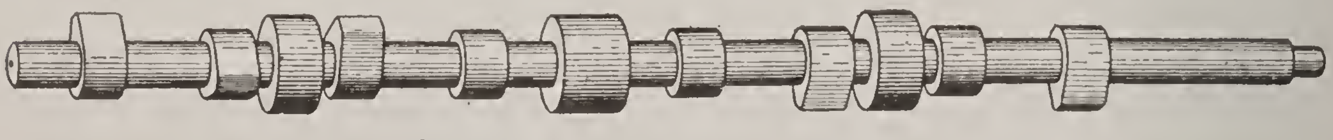


Fig. 159. Cams Integral with Shaft—Milling Machine Job

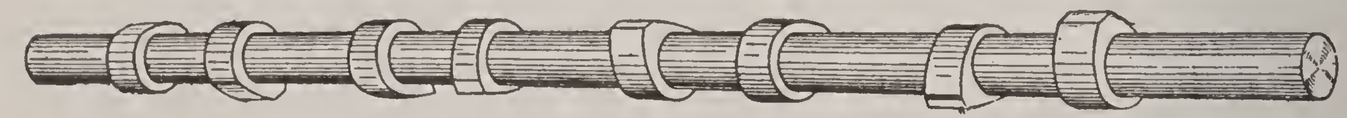


Fig. 160. Another Camshaft with Integral Cams

Grinding Increases Accuracy. An even later improvement in the way of a machine for producing cams on an integral shaft is the grinding machine which has been developed for this purpose. This works to what is called a master camshaft, that is, a larger size of shaft which has been very accurately finished. This master shaft is placed in the grinding machine, the construction of which is such that the grinding wheel follows the contour of the very accurate master shaft and produces a duplicate of it, only reduced in size, a reducing motion being used between master shaft and grinder-wheel shaft.

The result of this arrangement is a machine which is almost human in its action, for it moves outward for the high points on the cams and inward for the low spots on the shaft. Moreover, it has the further advantage that all shafts turned out are absolutely alike and thus accurately interchangeable. It allows also of another arrangement of the work, the drop forging of the shafts within a few thousandths of an inch in size; the surface of skin is easily ground off in one operation, then the hardening is done, and the final grinding to size is quickly accomplished. In this way, the shafts may be produced more cheaply than was formerly the case and have, in addition, the merits brought out above, namely, greater accuracy, superior interchangeability, and quicker production.

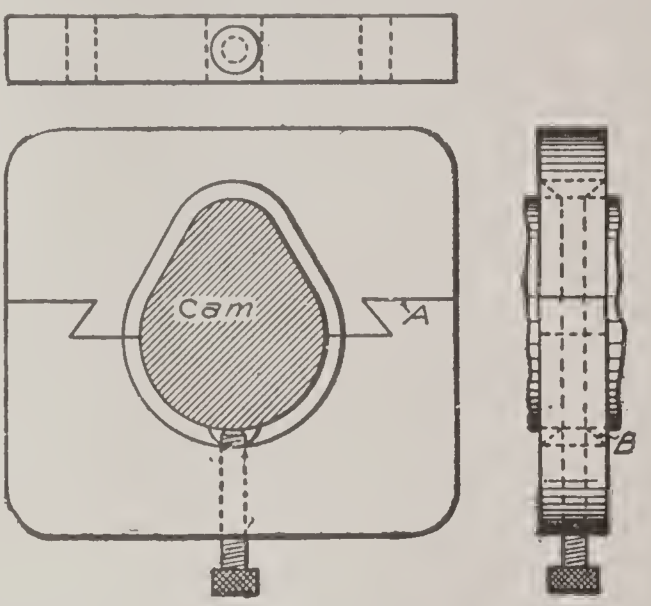


Fig. 161. Useful Form of Gage for Separate Cams

The same process is applicable to, and is used for, other parts of the modern motor car; thus crankshafts are ground, pump and magneto shafts are finished by grinding, and many other applications of this process are utilized. The process can be extended indefinitely, the only drawback being that a master shaft is very expensive.

Old Way Required More Accurate Inspection. With the old method of making the cams and shaft separate, the amount of inspection work was very great and represented a large total expense in the cost of the car. Thus, it was necessary to prove up every cam separately, as well as every shaft, and, later, the cams and shaft assembled. One of the forms of gages used for inspecting cams is shown in Fig. 161. It is in two pieces, dovetailed together. This allows of the testing of many shapes of cam with but one base piece and a number of upper, or profile, pieces equal to the number of different cams to be tested. To test, the cam is slipped into the opening, and if small, the set screw forces it up into the formed part of the gage, showing its deficiencies; while if large, it will not enter the form.

Valve Timing

This increase of speed without material alteration in the engine is what every repair man aims to get when he goes over the timing of the motor. Valve timing has been called an art, but it is not; it is only the application of common sense and the known valve diagram to the motor in an attempt to get the best all-around results. These, as might be expected, are a compromise, and that repair man does the best timing, who realizes this and, instead of attempting the impossible, simply produces the most desirable all-around compromise.

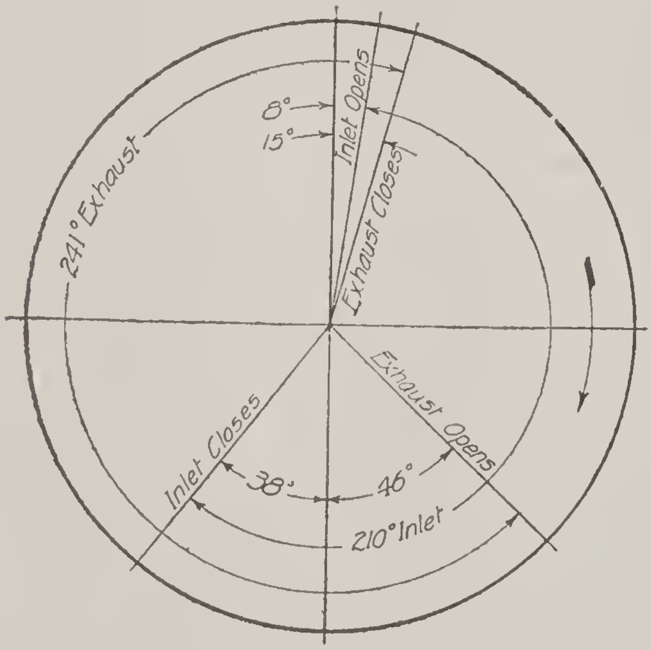


Fig. 162. Valve-Timing Diagram for 1915 Four-Cylinder Overland Motor
Courtesy of Willys-Overland Company, Toledo, Ohio

Flywheel Markings. Nearly all motors now have the timing marked upon the rim or face of the flywheel, so that it is unnecessary to bother with the crankshaft and pistons. This has been found by experience to be the best and handiest way, for the flywheel is generally accessible without removing many other parts. The same is true with the valves. This is not the case with pistons and crankshaft; moreover, with these it is difficult to determine the exact upper and lower dead centers, and still more difficult to work to angles.

To use these settings marked on the flywheel, a stationary pointer on the upper surface of the crankcase hangs over the flywheel surface as closely as possible and indicates the reading. The flywheel is turned by hand or by means of the crank at the front of the engine until a mark or the desired mark is brought up to the pointer. Thus, the cylinders are marked from front to back always, that nearest the radiator being 1, the next 2, then 3, and the last, in the case of a four-cylinder motor, 4. In a six-cylinder motor the method is the same with the addition of two cylinders, the one nearest the dash being, of course, 6. The flywheel sometimes has the positions marked on its surface, as well as the valve operations. Referring to Fig. 162, this shows the valve-timing diagram of the four-cylinder Overland for 1915. Notice in this that none of the valve operations begin or end on a dead center point so that even if the centers are marked on the flywheel (as they are in this case) this is of little benefit except as will be pointed out. The marks on the flywheel are as follows, this showing also what they indicate. In referring to these it will be remembered that on a four-cylinder crankshaft the first and fourth crankpins are up (or down) together, while the second and third are down (or up) together:

1-4 UP	Means that pistons in cylinders 1 and 4 are in their uppermost position, or at upper dead center.
2-3 UP	Means that pistons in cylinders 2 and 3 are in their uppermost position, or at upper dead center.
1-4 I-O	Means that inlet valve of cylinder 1 or 4 (not both) opens.
1-4 I-C	Means inlet valve of cylinder 1 or 4 closes.
1-4 E-O	Means exhaust valve of cylinder 1 or 4 opens.
1-4 E-C	Means exhaust valve of cylinder 1 or 4 closes.
2-3 I-O	Means inlet of cylinder 2 or 3 opens.
2-3 I-C	Means inlet of cylinder 2 or 3 closes.
2-3 E-O	Means exhaust of cylinder 2 or 3 opens.
2-3 E-C	Means exhaust of cylinder 2 or 3 closes.

The firing order of the cylinders is 1- 3- 4- 2. To apply this knowledge, open the pet cocks so the motor will turn over easily; selecting cylinder 1 to start with, turn the flywheel until the mark 1-4 UP comes to the pointer at the top. Now continue turning to the left (at the rear end) about an inch more when the mark 1-4 I-O will be seen. Bring this slowly up to the pointer, when the inlet valve should just begin to open. This can be noted by feeling the stem, or by placing a wire upon the top of the valve and noting when it begins to be pushed upward by the valve movement. If this should happen in cylinder 4 instead of 1, turn the flywheel one complete revolution, bringing the same point to the top. If this is entirely correct, the flywheel can be turned in the same direction about 5 to 6 inches more than half a turn, when the mark 1-4 I-C will appear. Turn slowly until it reaches the pointer, when the valve in cylinder 1 should be completely closed. This can be determined again by feeling of the valve stem which should come down to its lowest position, or by the wire on the top of the valve. At this point the valve-tappet clearance comes in. When the valve tappet has reached its lowest point, and the valve has been allowed to seat, the tappet should go down slightly farther than the valve, leaving a very small space between the two. This is the clearance and it varies in normal engines from .002 inch to .012 inch. In the motor which is being described it is .012 inch. The closest approximation to this is an ordinary visiting card, which is about .012 inch thick; when a motor is handled which has less, very much less, this can be approximated by means of cigarette papers which are very close to .003 inch thick. These are used in the absence of precise metal thickness gages, or feelers, as they are called.

Valve-Stem Clearance. This clearance is necessary to compensate for the expansion of the valve stem when it becomes highly heated during the operation of the engine; the tappet or push rod does not become heated, consequently it does not expand. Practically all motors are made with an adjustment here in the form of a screw with a hexagon head which is hardened where it strikes the valve stem or it is recessed out for a piece of hard fiber to deaden the noise, Fig. 151, and the fiber is locked in the desired position by means of a lock nut. If the clearance is less than the required amount or greater so that the motor is very noisy, the lock nut is loosened, and the screw gradually turned upward until it just begins to grip the visiting card. This should be done very carefully, for if the clearance is made too small, the valve will not seat fully when the motor is hot and the valve has expanded; on the other hand, if the clearance is made too large, the push rod will come up against the valve end each time with a bang, and eight of these repeated a thousand times a minute make a great deal of disagreeable and useless noise. In the modern motor, the cams are made an integral part of the camshaft. If the driving gear for the camshaft is in its right place, and the camshaft bearings are all in good shape, this push rod adjustment is the only valve adjustment possible. If the timing is not correct, that is, if none of the valve operations correspond with the marks on the flywheel and the maker's instructions, then the cam gear has been misplaced.

Exhaust-Valve Setting. The same procedure is followed through for the exhaust valve of the same cylinder, continuing past the 1-4 UP mark to the mark 1-4 E-O. At this point the exhaust valve of cylinder 1 should just begin to open. Then continue around to the 1-4 E-C point where the exhaust valve of cylinder 1 is just completing its downward, or closing, movement. If there should be any need for adjustment here, as described previously, this should be made before proceeding to the other cylinders. It should be stated that many makers give the exhaust-valve stems slightly greater clearance than the inlets, on the assumption that they work with hotter gases, are subjected to more heat, and should therefore expand more. The make being described has the same clearance for both.

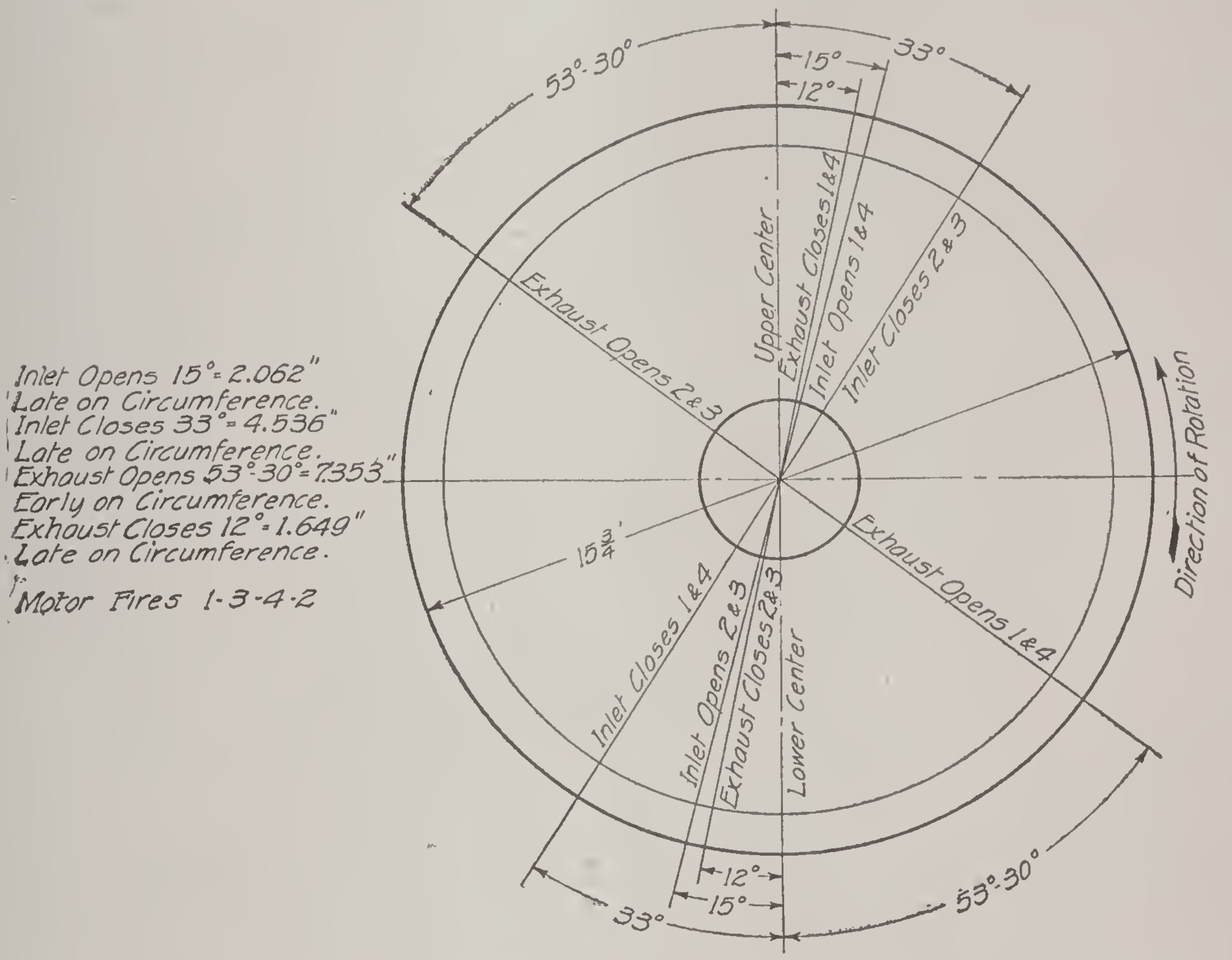


Fig. 163. Valve-Timing Diagram for Four-Cylinder Hudson Motor Indicating All Cylinders
Courtesy of Hudson Motor Car Company, Detroit, Michigan

Relation of Settings in Each Cylinder. Now, having checked up and adjusted both valves for cylinder 1, follow through the same process for cylinder 4, and, after that, of cylinder 2, then 3. The diagram, Fig. 162, shows but the cycle in each cylinder, while the description above simply listed the markings to be found on the flywheel, so the additional diagram, Fig. 163, is given to show the relation of these marks to one another. This diagram refers to a different motor, a Hudson four-cylinder model, and the timing is indicated on the face, but the repair man will understand that this is done simply for convenience, and that these marks are actually found on the rim. So, too, the lines drawn down to the center are simply shown for convenience in indicating the angles and do not appear on the flywheel.

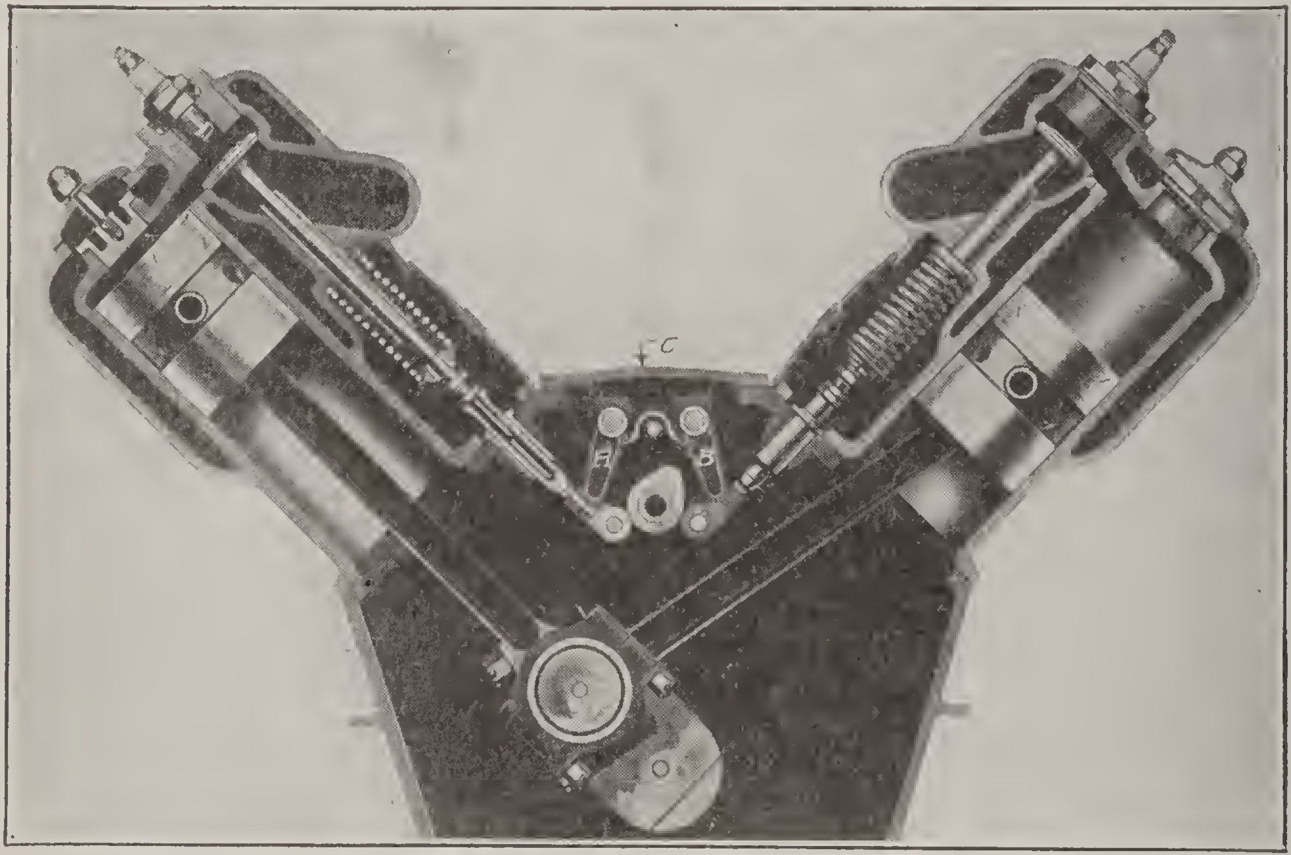


Fig. 164. Section through Cadillac Eight, Showing Camshaft and Valve Mechanism
Courtesy of Cadillac Motor Car Company, Detroit, Michigan

In this a different timing will be noted, in that the inlet opens later and closes earlier, while the exhaust opens earlier and closes earlier.

System Applies to All Types of Motors. As has been stated previously, discussed, and shown in Tables I and II, there is, and always has been, a wide divergence among designers on the subject of valve timing, so that the repair man must look for a different setting with each different make, and often a different setting with each different model of the same make. All that can be used for all cars is the general method. The general method, however, is applicable whether the valves are all on one side (**L**-head cylinders), half on each side (T-head cylinders), all in the head or half on one side and the other half in the head, in short, regardless of the valve position. Similarly with regard to numbers, the method holds good regardless of the number of valves per cylinder. Moreover, it applies regardless of the number and arrangement of the cylinders, as it is just as good for eights and twelves as for the four described. On V-type motors there is a close relation between the opposing cylinders, right-hand No. 1 and left-hand No. 1, and this must be taken into account. In some motors there is a cam for each valve, in which case no trouble would ensue; but in others there are but eight cams for the sixteen valves (of an eight-cylinder motor). This type of shaft will influence the timing diagram, and in setting, the repair man will have to concern himself with the same cam for two different valves—one in a cylinder of the right-hand group and one in a cylinder of the left-hand group.

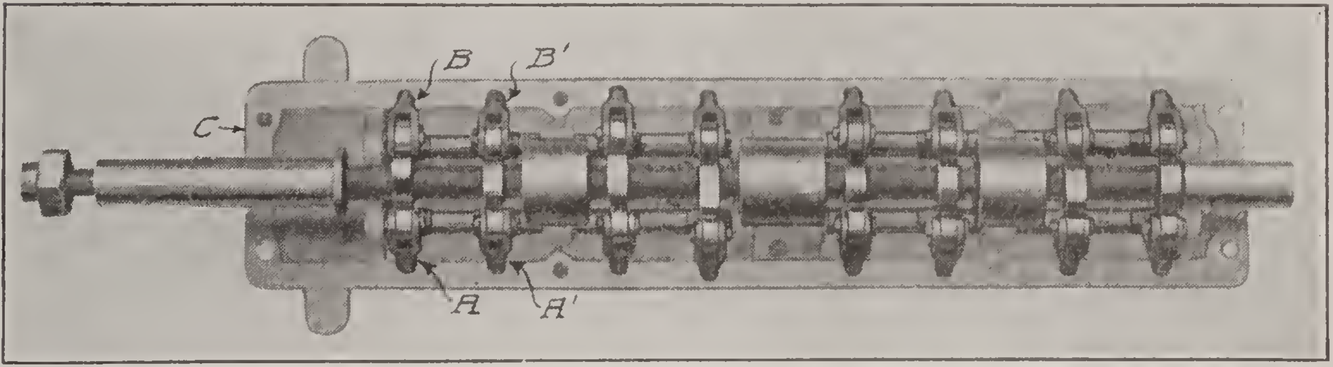


Fig. 165. Cadillac Camshaft, Cam Followers, and Covers Removed from Motor

This statement will be more plain perhaps if reference is made to Fig. 164, which shows a section through the Cadillac eight for 1917, and indicates how the one cam operates two valves through the hinged rocker arms *A* on the left-hand cylinder and *B* on the right for the right-hand cylinder. By comparison, see also Fig. 165, which shows the plate *C* in Fig. 164 removed and turned upside down, with the camshaft and rockers complete. Not all eights and twelves are like this, nor do all have a single camshaft set in the middle of the V; on the contrary, one well-known twelve-cylinder motor, the National, has the valves on the outside of the two groups of cylinders, and thus has two camshafts. In such a case, the timing method just described would be followed through for all the cylinders on one block, then the same system would be followed through on the other side of the engine, one cylinder after another, on that block.

Repairing Poppet Valves and Valve Parts

The interest of the repair man in all these valve-motion parts is quite different from that of the designer, for he cares not so much how they are made as how they are taken out, repaired, and put back, when accident or wear make this work necessary. To the repair man suitable tools for doing this kind of work are also of interest, particularly those for reaching inaccessible parts or for doing things which without the tools could not be done.

Curing a Noisy Tappet. Valve springs and the valves themselves, either at the seat end or at the tappet end, give the most trouble. For example, when the clearance between the end of the tappet and the end of the valve (usually from .003 to .008 inch) is too great, a metallic click results. Often this noise from the tappet is mistaken for a motor knock; but the skilled repair man has little trouble in finding and remedying it, for, even if he cannot measure in thousandths of an inch, he knows, for instance, that the ordinary cigarette paper is about .003 inch in thickness, and from this he can estimate .003, .006, or .009 inch. Ordinary thin wrapping paper is well known to be about .005 inch; with this alone, or in combination with cigarette papers, he can obtain .005, .008, .010, and .011 inch, practically all the variation he is likely to need.

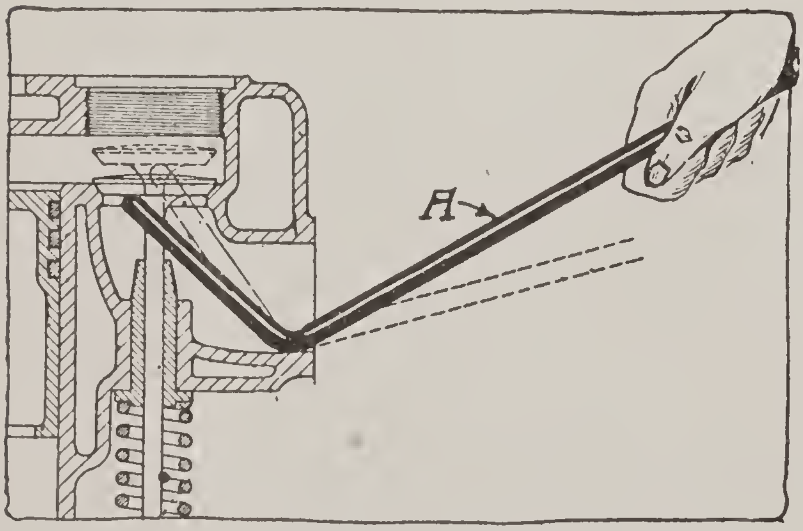


Fig. 166. Bent Tool Which Facilitates Removal of Stuck Valves

Removing Valve. Getting the valve out frequently gives much trouble; the valve is often found frozen to its seat or to the stem gummed in its guide. A tool to meet this difficulty is a plain bar or round iron about $\frac{1}{4}$ inch in diameter, Fig. 166, with one end, for a distance of perhaps 2 or $2\frac{1}{2}$ inches, bent up at an angle of about 120 degrees. To use the tool, insert the short bent end in the exhaust or the inlet opening, according to which valve is stuck, until the end touches the under side of the valve head, then lower the outer end until the bottom of the bent part or point at which the bend occurs rests against solid metal. The outer end can now be pressed down, and, with the inner end acting as a lever, the valve can be pressed off its seat and out very quickly.

To make this clearer, the rod, Fig. 166, is indicated at *A*, while the dotted line shows how it is pressed down and the valve forced out. The garage man can elaborate upon the tool when making it for himself by using square stock; it has the inner end forked so as to bear on each side of the valve. The form pointed out above is the simplest, cheapest, and easiest to make.

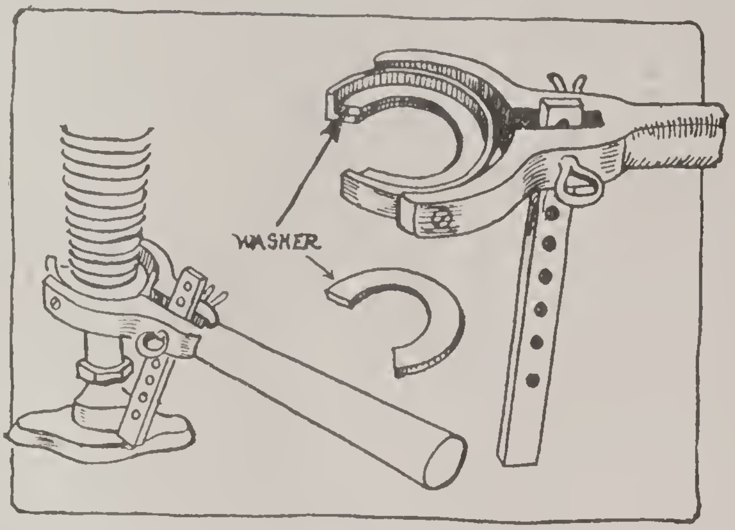


Fig. 167. Easily Made Tool for Removing Valve Spring

Removing Valve Spring. Taking out the valve spring is frequently difficult for various reasons; perhaps the springs are very stiff, or they may have rusted to the valve cups at the bottom, or the design may not allow room enough to work, etc. At any rate the removal is difficult, and a tool which will help in this and which is simple and cheap, is in demand. Many motor cylinders are cast with a slight projection, or shelf, opposite the valve-spring positions, so that one only needs a tool that will encircle the lower end of the valve spring and rest upon this ledge and give an outer leverage.

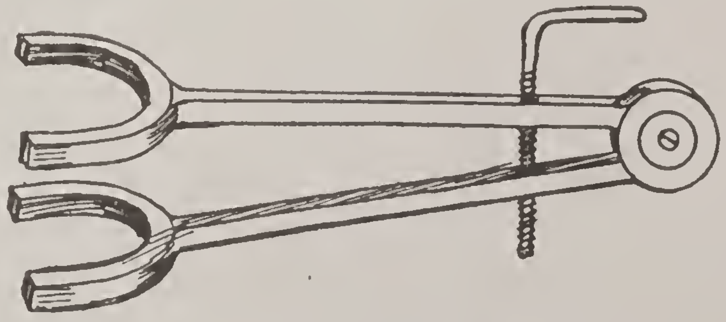


Fig. 168. Type of Valve-Spring Tool Which Leaves the Hands Free

Types of Valve Removers. In working on cylinders that do not have this cast projection, a tool like that shown in Fig. 167 is useful. It consists of a yoke for encircling the lower end of valve spring and cup, with a long outer arm for prying, and a slot into which a drilled bar is set. This bar is placed in various positions according to the kind of motor which is being worked on; when removing a valve-spring key, the lower end of the bar rests upon the crankcase upper surface, or upon the push-rod upper surface if that is extended. After slipping the grooved yoke under the spring cup, a simple pressure on the outer end raises the valve so the key can be withdrawn. Then the removal of the tool allows the valve spring to drop down, and the valve is free

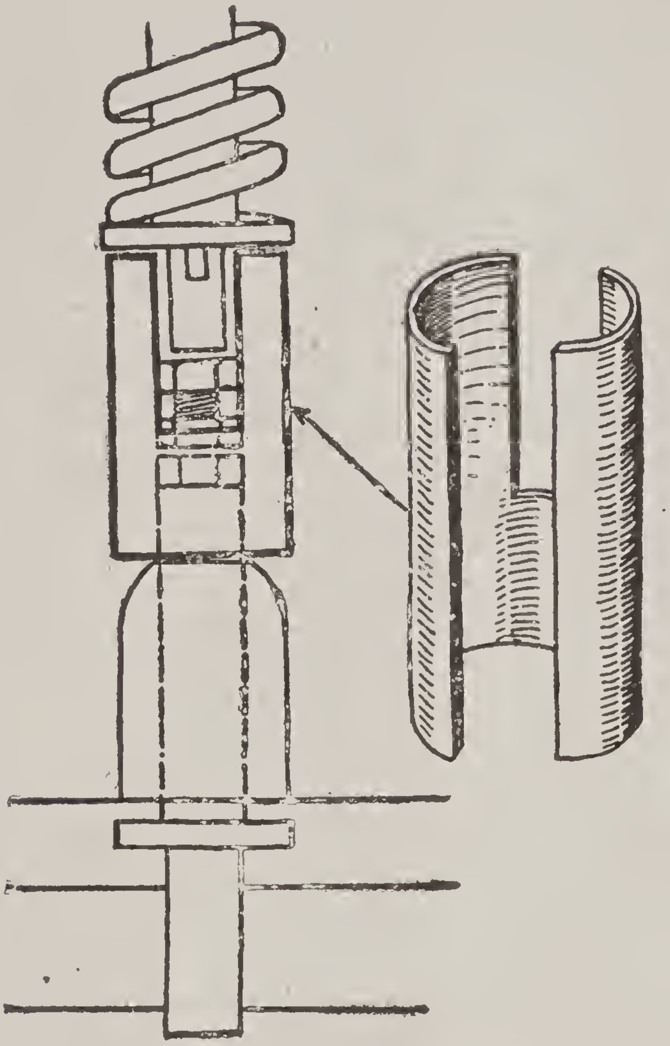


Fig. 169. Substitute for a Valve Spring Remover Which Pushes Spring away as Motor is Turned

The valve spring may be removed in two other ways by the use of the two tools shown in Figs. 168 and 169. In the former, the idea is to compress the spring only, no other part being touched. This tool, once set, will continue to hold the spring compressed, leaving the hands free—a decided advantage over the tool shown in Fig. 167. This device consists, as the illustration shows, of a pair of arms with forked inner ends and with outer ends joined by a pin. A bent-handled screw draws the ends together or separates them, according to which way it is turned.

The simplest tool of all is the one shown in Fig. 169. It is a formed piece of stiff sheet metal which is set into place when the valve is open, and when the valve is closed by turning the motor, the sheet-metal piece holds the spring up in its compressed position.

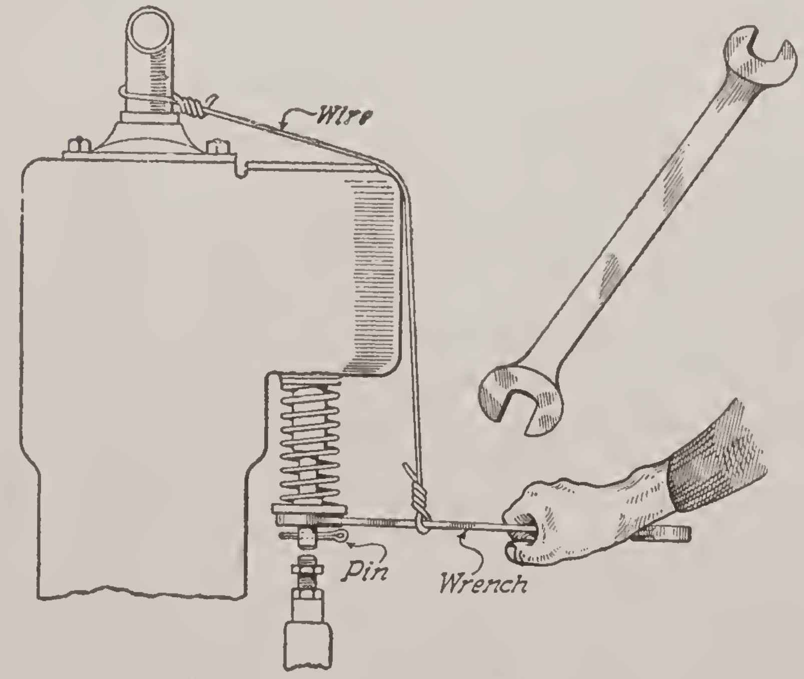


Fig. 170. Method of Compressing Valve Spring without Special Tool
Courtesy of "Motor World"

There are almost as many different valve and valve-spring removers as there are different cars or different motors. However, the simple makeshift shown in Fig. 170 is worthy of mention. Lacking a form of valve- or spring-removing tool, this repair man simply supported a plain double-ended wrench by means of a wire attached to the water pipe on top of the motor; adjusting the length of it so that the end of the wrench would just slip under the valve key, he was able to remove the pin, which freed the spring and thus the valve. Practically the same thing was evolved by another repair man who took a wrench of this type and drilled a hole through the center of the handle which was first twisted through a right angle. Then he bent a piece of stout wire into the form of a hook, one end through the wrench, the other over some projection on the engine. With the hook removed, the wrench was not radically different from any other and could be used as freely; with the hook in, he had a simple valve-spring removing tool.

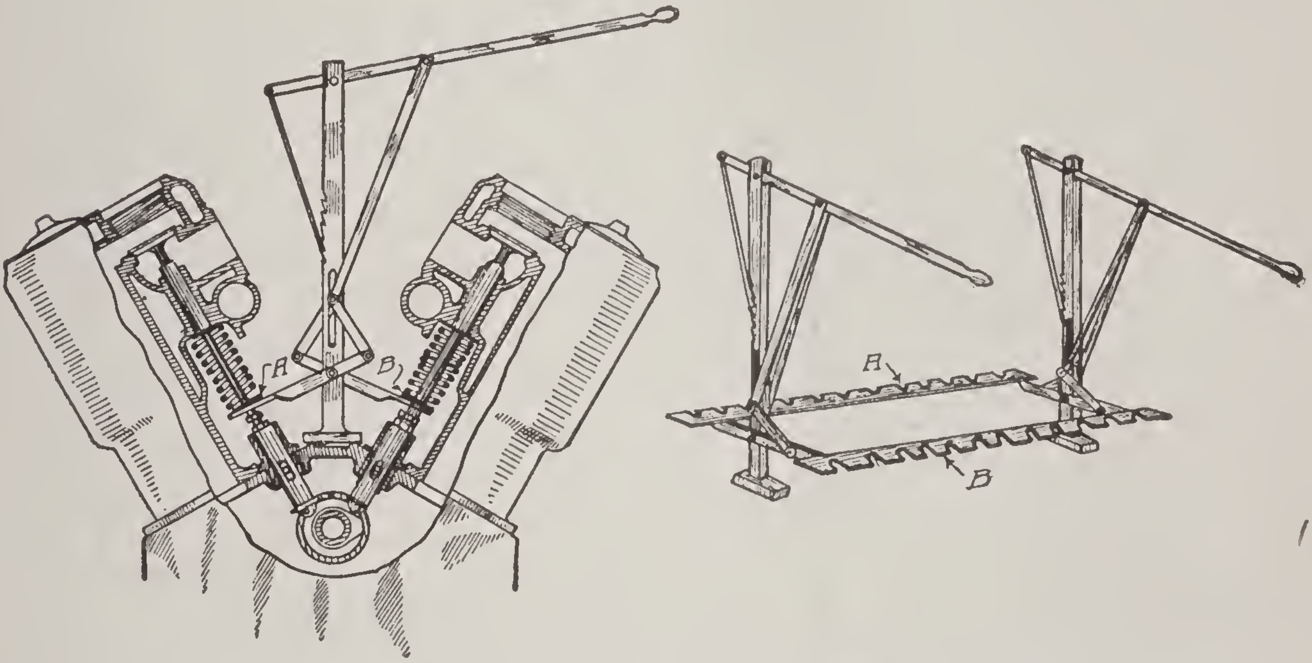


Fig. 171. Method of Compressing All Twenty-Four Packard Valve Springs at Once
Courtesy of "Motor World"

Twelve-Cylinder Valve Remover. One of the objections raised to the twelve-cylinder motor is the trouble of removing and grinding all the valves. The Philadelphia Branch of the Packard Company has overcome this disadvantage by constructing the special tool shown in Fig. 171. This lifts the whole 24 valves at once. It consists of the central stand, which rests on the flat top of the crankcase, having a long arm and connected levers at the bottom to work the spring compressors. These, as will be seen at *A* and *B*, are really the special feature of the outfit, as they are specially constructed to fit around the valves in sets of 12 each. A ratchet holds the device locked, so that after it is applied and fitted to all the valves, they can be forced up and locked; then the matter of valve removal, regrinding, and replacement can be handled for the whole 24. At its conclusion, the rigging can be unlocked and all 24 valves freed at once.

Holding Valve Springs Compressed. Many times there is a need for holding the spring in its compressed form, as, for instance, when the valve is removed with the positive certainty that it will be replaced within four or five minutes. In such a case a clamp which will hold it in compression is very useful, for it saves both time and work. These may be made to the form shown in Fig. 172 in a few minutes' time, for they consist simply of a pair of sheet-metal strips with the ends bent over to form a very wide U-shape. A pair of these is made for each separate make of valve spring, because of the varying lengths, but they are so easily and quickly made that this is no disadvantage.

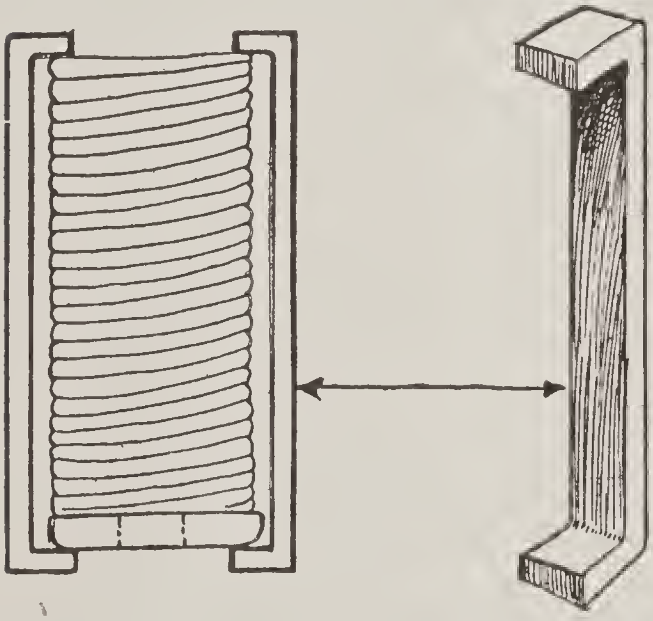


Fig. 172. Spring Clamp, Which Is Easily Made and Saves Much Work and Trouble

In many shops, after getting in the habit of making these clamps, the workmen take this way of replacing the spring in preference to all others. After removal of the valve, the spring may be compressed in a vise and a pair of the clamps put on. Then when the valve is ready to go back in, the spring is as easy to handle as any other part. This is especially true when replacing the spring retainer and its lock.

Stretching and Tempering Valve Springs. Many times when valve springs become weakened, they can be stretched to their former length, so that their original strength is restored. This can be done by removing them and stretching each individual coil, taking care to do it as evenly as possible. When well stretched, it is advisable to leave the coils that way for several days. This method will not, of course, restore the strength permanently; it is at best a makeshift, for in the course of a few thousand miles the springs will be as bad as before.

Sometimes weakened valve springs may be renewed by retempering, on the theory that the original temper was not good or they would not have broken down in use. The tempering is done by heating to a blood-red color and quenching in whale oil. If this is not successful, new springs are advised.

Adjusting Tension of Valves. Unless all the valves on a motor agree, it will run irregularly, that is, all the exhausts must be of the same tension, and all the inlets must agree among themselves, though not necessarily with the exhausts. Many times irregular running of this kind, called galloping, is more difficult to trace and remove than missing or some other form of more serious trouble, and it is fully as annoying to the owner as missing would be.

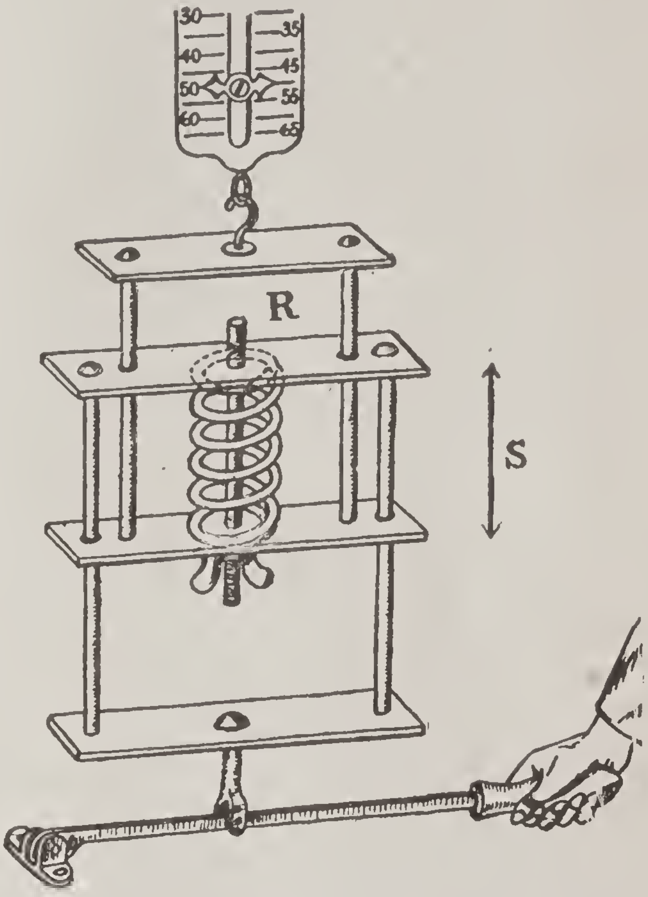


Fig. 173. Simple Rigging for Testing Valve-Spring Pressure and Strength

To be certain of finding this trouble, the repair man should have a means of testing the strength of springs; a simple device for this purpose is shown in Fig. 173. As will be seen, this consists of sheet-metal strips and connecting rods of light stock, with a hook at the top for a spring balance and a connection at the bottom to a pivoted hand lever for compressing the spring. By means of the center rod at *R* and the thumb screw at the bottom, the exact pressure required to compress the spring to a certain size may be determined. Suppose the spring should compress from 4 inches to 3½ inches under 50 pounds. By compressing it in the center portion of the device, so that the distance between the two adjacent strips of metal indicated by *S* is just 3½ inches, the spring balance should show just 50 pounds. If it shows any less, the spring is too weak and should be discarded; if it shows any more, it is stronger than normal —which is desirable if all the other springs on the same engine are also stronger.

If only a quick comparison of four springs is desired, the device can be made without the bottom lever, as the setting of *S* at a definite figure—say to a template of exact length—would call for a certain reading of the scale of the spring balance.

Cutting Valve=Key Slots. Cutting valve-key slots in valve stems is another mean job which the repair man frequently meets. He runs across this in repairing old cars for which he has to make new valves; and at other times for other repairs. The best plan is to make a simple jig which will hold, guide, and measure all these things at once, as all are important. Such a jig is shown in Fig. 174. It consists of a piece of round or other bar stock, in which a central longitudinal hole is drilled to fit the valve stem, one end being threaded for a set screw. Near the other end of the jig, three holes, of such a diameter as to correspond with the width of key slot desired, are drilled in from the side. These are so placed that the length from the top of the upper hole to the bottom of the lower gives the length of key seat desired. Opposite the three drilled holes and at right angles to them, another hole is drilled and tapped for a set screw.

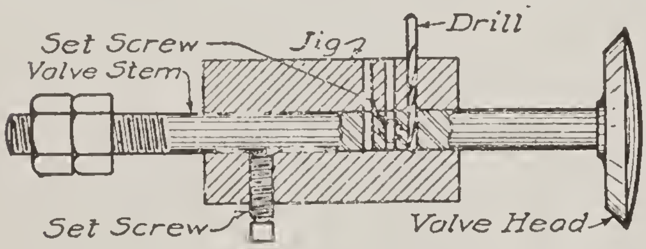


Fig. 174. Cheap Jig for Slotting Valve Stems

To use the device, slip the valve in place and set the bottom screw of the jig so as to bring the three drilled holes at the correct height for the location of the key seat. Then the three holes are drilled, and the valve is moved upward so that the space between the holes is opposite a guide hole, and two more holes are drilled to take out the metal between. The five holes will give a fairly clean slot, which needs a little cleaning out with a file before using.

Grinding the Valves. The new driver must learn when to grind his valves, that is, how often, and he must also learn to do the work properly. There is no hard and fast rule which can be given aside from grinding when it is necessary. A careful driver may get four to five thousand miles out of his valves with one grinding, while another may get only one or two thousand miles with the selfsame car and engine. There are many factors which enter into the life of a valve seat, and, in the frequency of grinding, all of these have to be taken into account. Some of these are: imperfect cooling of the seats; too strong springs, which cause hammering and thus wear out the seats prematurely; over-lubricating, which causes spitting and sooting, both of which reduce the active life of the valve seat.

Another cause for frequent grinding is contributory negligence on the part of the driver. He does not examine them as often as he should, and the result is failure to discover something in the way of soot or dust caught in between the valve and seat, which is being gradually pressed into the seat.

Regrinding Process. When either the valve head or seat has become worn or pitted, it must be reground as follows: Secure a small amount of flour of emery, the finer the better, and mix this into a thin paste using cylinder oil, or graphite, or both. Loosen the valve, disconnect all attachments, remove the valve cap above, and free the valve in a vertical direction. Now lift it out, place a daub of the emery paste on the seat, and replace the valve. With a large screwdriver press the valve firmly in place, at the same time rotating it. about one-fourth of a turn to the right and then the same amount to the left.

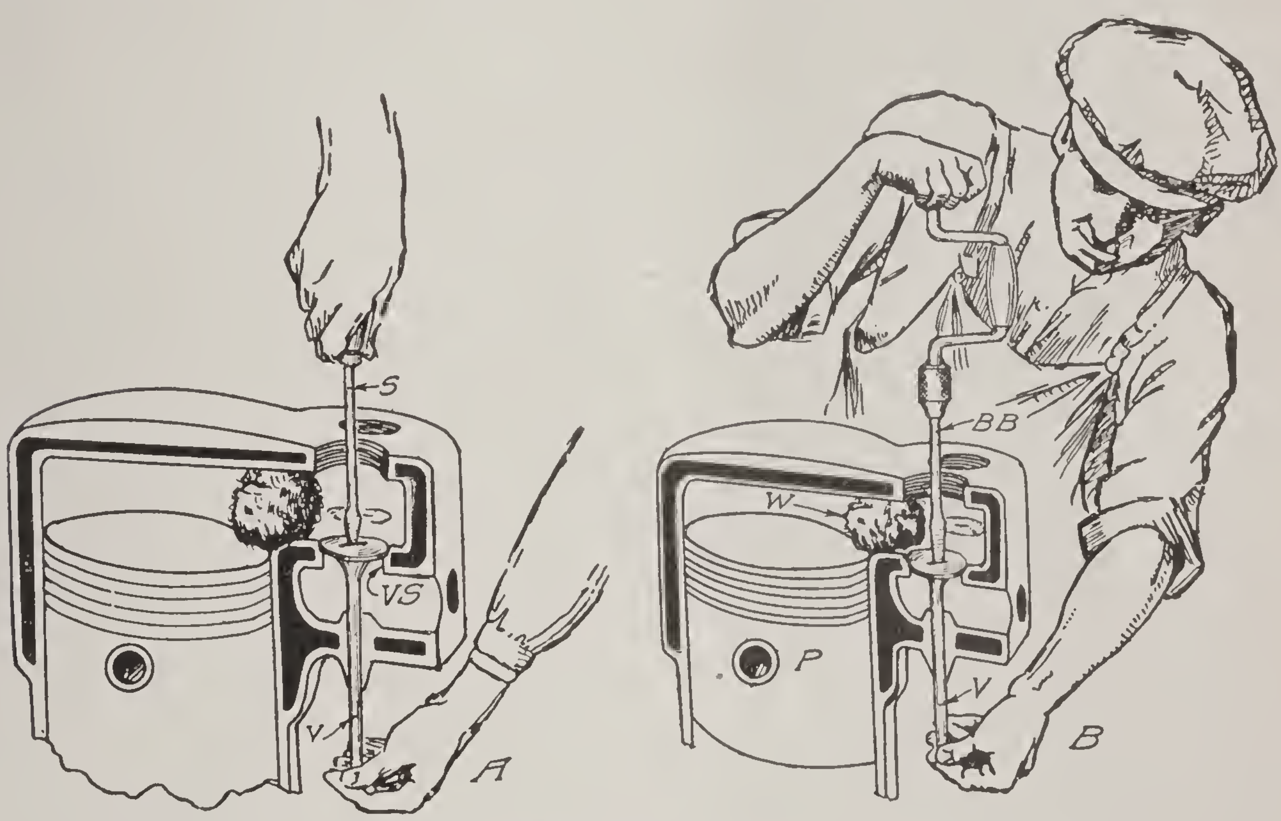


Fig. 175. Two methods of Grinding-In Valves: (*A*) by Hand, Using a Screwdriver; (*B*) with Brace, Screwdriver and Bit

This is shown in Fig. 175-*A*, in which *S* is the screwdriver, *V* the valve, and *VS* the valve seat. Note how the right hand presses down on the screwdriver and turns it at the same time. While this is being done, the left hand should be held right below the valve stem with one finger just touching it. After moving back and forth about eight or ten times, lift the valve off its seat with the finger, turn it through a quarter-turn, and drop it back into place. Then repeat the grinding until the whole circle has been covered several times. Then remove the valve and clean off both moving member and seat with gasoline. Mark the seat on the valve with a slight touch of Prussian blue, replace the valve, and twirl it around several times so as to distribute the color. Remove the valve without touching the seat portion on it or in the cylinder, and examine both. If the grinding process has been complete and accurate, the color will have been distributed in a continuous band of equal width all around the surface. If not continuous, or not of equal width all around, the task is but partially completed and must be continued until the full streak results. On the first attempt at this rather delicate piece of work, it is well to call in an expert repair man to examine and pass upon the job.

In Fig. 175-*B* the same process is shown, but a brace, screwdriver and bit are used in place of the slower screwdriver. This method would hardly be advocated for an amateur attempting his first job of valve grinding, but as soon as some proficiency has been attained, it is the best, quickest, and most thorough method.

There are, of course, a number of tools now on the market for grinding valves; some of these are constructed in such a manner as to do all the work, namely, the partial turn and reverse on the grinding stroke, then the lift and partial revolution, then dropping the valve down on the seat again, and repeat. The use of one of these reduces the act of valve grinding down to a matter of knowing how to apply the emery and when and how to stop.

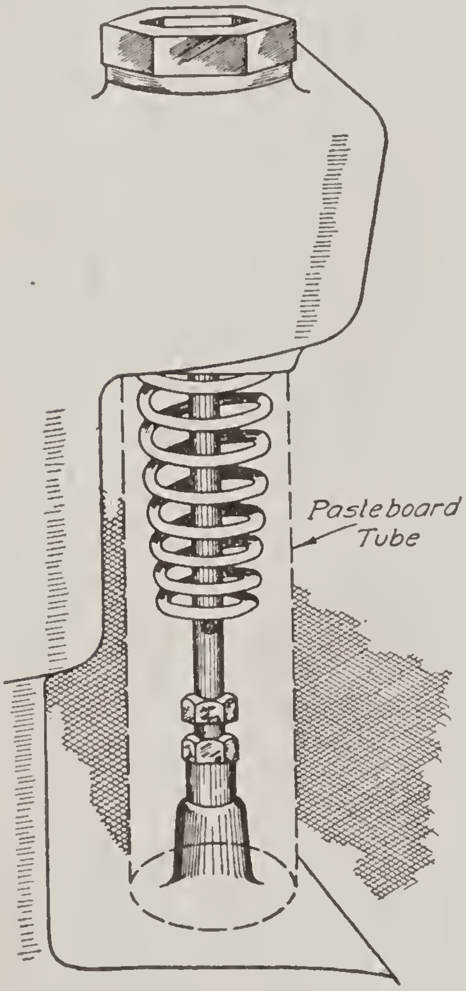


Fig. 176. Method of Enclosing Valve Action with Pasteboard Tube to Stop Noise and Improve Lubrication

Noisy Valves. Sometimes the valves get very noisy and bother the driver a great deal in this way, that is to say, the wear in the valve-operating system becomes so considerable as to make a noise every time a valve is opened or closed. With the engine running at slow speeds, each one of these is heard as a separate small noise and not much is thought of it, but when the motor is speeded up, the noises all increase and become continuous and very noticeable. This may be remedied by taking up on the valve tappets which usually are made adjustable for this purpose. They should be taken up until there is but a few thousandths of an inch between the valve tappet and the lower end of the valve stem. A good way to measure this is to adjust until one thickness of tissue paper will just pass between the two; then there is approximately .003 inch between them.

Valve Enclosures. On many old cars, the arrangement of the valve mechanism is such that, after several thousand miles have been covered, the valve motions will become noisy and nothing that can be done will stop this. In that case, the best plan is to enclose each one of them in a pasteboard or other tube and thus keep the noise in. In fact, this is a good plan even for later models. The method of doing this is indicated in Fig. 176, in which the pasteboard tube is shown in place around the valve mechanism. As this should be a tight fit between the crankcase at the bottom and the cylinder at the top, the tube must be slit in order to get it on. When this has been done, however, the tube can be drawn together and fastened by means of wire or otherwise. Besides reducing the noise, it will be found that the valve system parts will get better lubrication in this way and will pick up less dirt and dust, thus wearing less.

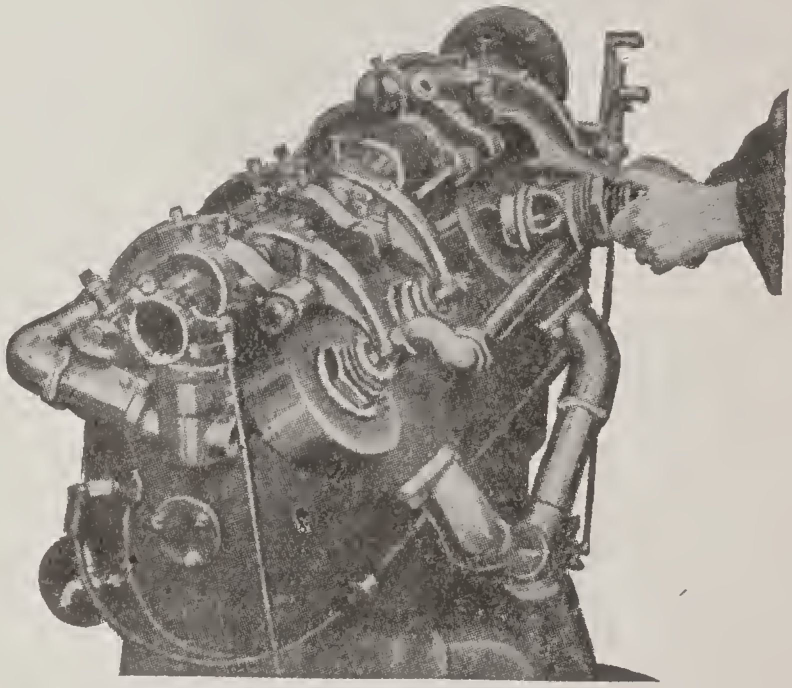


Fig. 177. Removing Valves from a Truscott Marine Engine

Taking Out a Valve. On some engines the job of taking out a valve or valves is not as simple as it sounds. On an overhead engine, or an engine with overhead valves, it is not as hard work as on an engine with the valves in pockets in the side of the cylinder, for the overhead valves are usually set into removable seats. The latter come out by simply taking off a yoke or, at most, a pair of nuts, and then the cage and with it the valve lifts right out, spring and all. This latter is mentioned because with the ordinary **L-** or **T-**head motor, it is the spring which causes all the trouble. Fig. 177 shows the process of removing the cage and valve from an engine with overhead valves (this is the engine made for the Truscott boats). To remove these, the valve tappet is held out of the way and the cage unscrewed.

Troubles with Inlet Valve. The inlet valve is often the seat of the trouble, and missing here is generally caused by a weak or broken spring, a bent stem, or a carbonized valve. If the valve spring has lost its temper and broken down, the tension will be insufficient to properly hold the valve on its seat, and the gas will partially escape and so cause missing. The insertion of an iron washer or two will increase the tension of the defective spring and serve as a temporary road repair. A broken spring may be similarly repaired by placing a washer between the broken ends. A bent valve stem should be taken out and carefully straightened by laying it upon a billet of wood with another block interposed between it and the hammer. Only a very little force is needed, and the stem should be repeatedly tried until it slides freely in its guide.

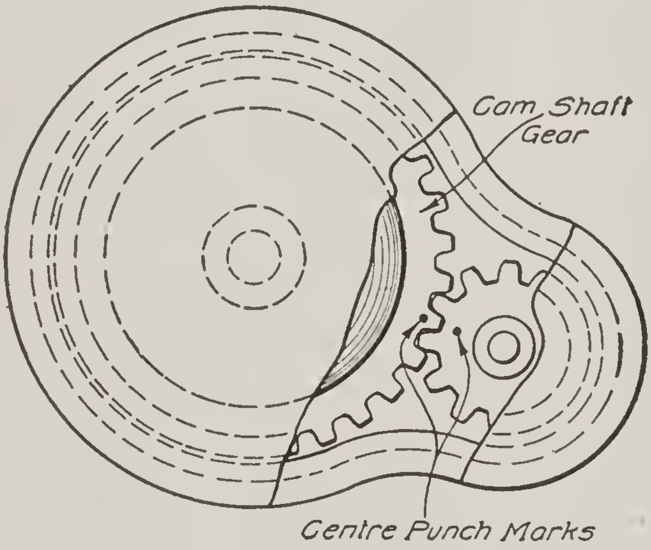


Fig. 178. Marking Timing Gears Is a Simple Job and Saves Much Time and Trouble

Valve Timing Gears. As has been stated, the camshaft is generally gear-driven from a crankshaft by a pair of two-to-one reduction gears; these are simple spur gears with straight or spiral teeth. As the one gear is keyed to the crankshaft and the other to the camshaft, it is highly important that these two gears be meshed in an exact manner. If one of them is out as little as one tooth, the difference in the running of the engine will be very marked. The timing previously mentioned under the head of Valve Timing will not be obtained; either all operations will occur later than the valve timing diagram and instructions call for, or else all these will be earlier. In either case, there will be a loss of speed and power, accompanied by noise, and the engine will not throttle down or speed.

To avoid this difficulty for the repair man, all gears are set and marked correctly at the factory. The marking is done in several ways. One is by lines cut on the gears when correctly meshed, so that if the gears are correctly meshed later, the part of a line on one gear will be a prolongation of the part on the other. Another way is to use center punch marks, one mark between the teeth on one and on the tooth meshing with these on the other. Then, if a second place has to be marked, two prick-punch marks are used in a similar manner, and if a third is marked, three punch marks. A third method is the use of numbers, the first pair marked being numbered *1* on each gear at the point of meshing, the second pair marked *2* on each, etc.

For the second method, all that is necessary is a prick punch and hammer, used in the manner shown in Fig. 178. When there are but two gears, as in the case shown, it is easy to make one hole between two teeth on one gear and another which lines up with it and as close to it as possible on the other gear. Where there are three, four, or more gears, the usual practice is to make the first and third with two prick-punch marks on each, the others with three, four, etc.

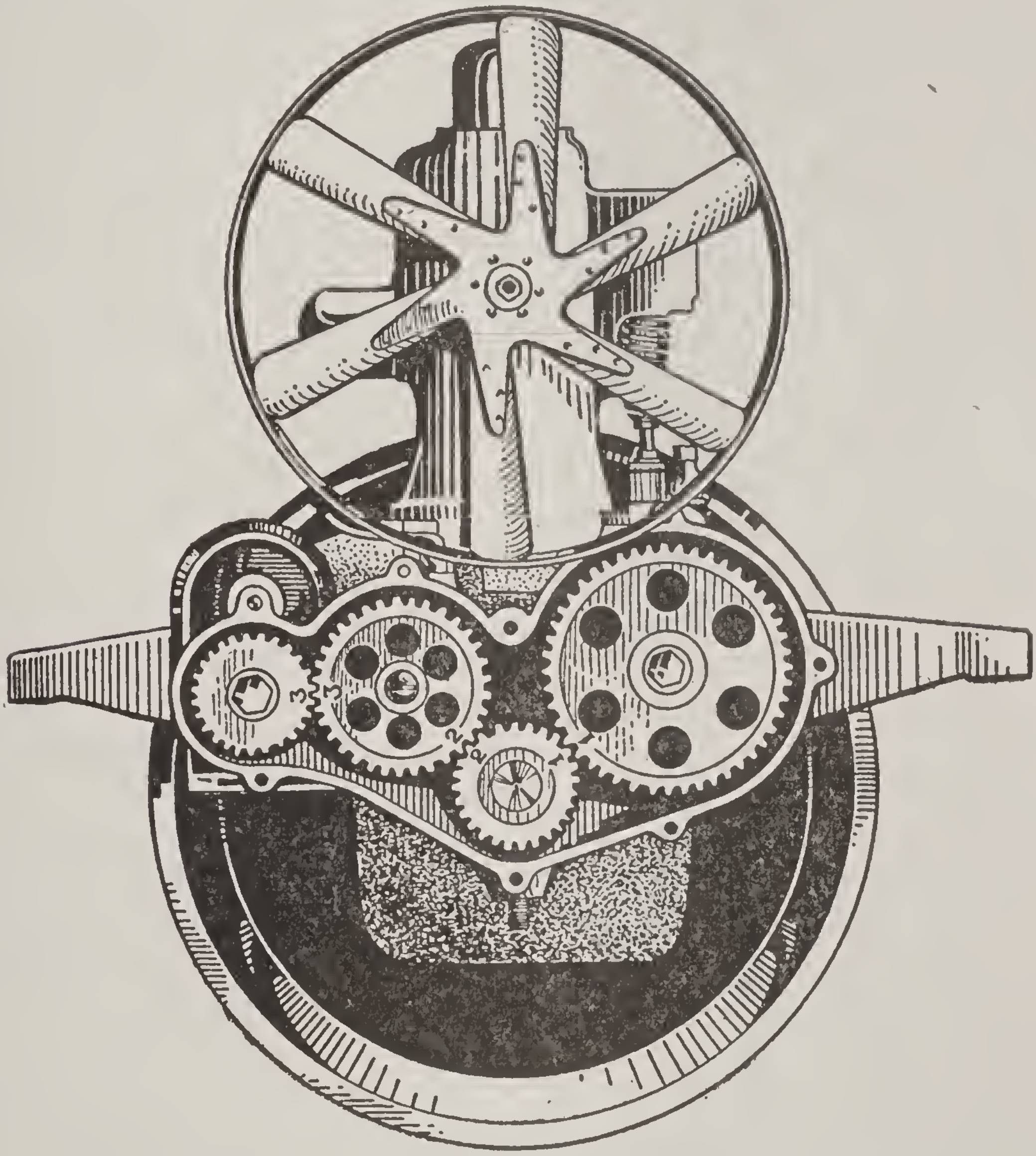


Fig. 179. Method of Marking Timing Gears by Means of Numbers

For the third method, or the use of numbers, see the set of gears shown in Fig. 179. This figure is that of the engine whose timing was described and shown in Fig. 162. It has four gears; from right to left they are camshaft gear, crankshaft gear, idler gear, and magneto gear. As will be noted, the crankshaft gear meshes with two others, so it must be marked in two places, *1* where it meshes with the camshaft gear and *2* where it meshes with the idler. A moment's thought will show, however, that it could never be replaced in the wrong manner, since it is marked only on the outside face, its *1* and *2* figures show where it matches a *1* mark on one gear and a *2* mark on another.

Chain Drive for Camshafts. The silent chain has gained much popularity for camshaft and accessory drives in the last two years for a number of reasons. It saves the use of idler gears in such cases as

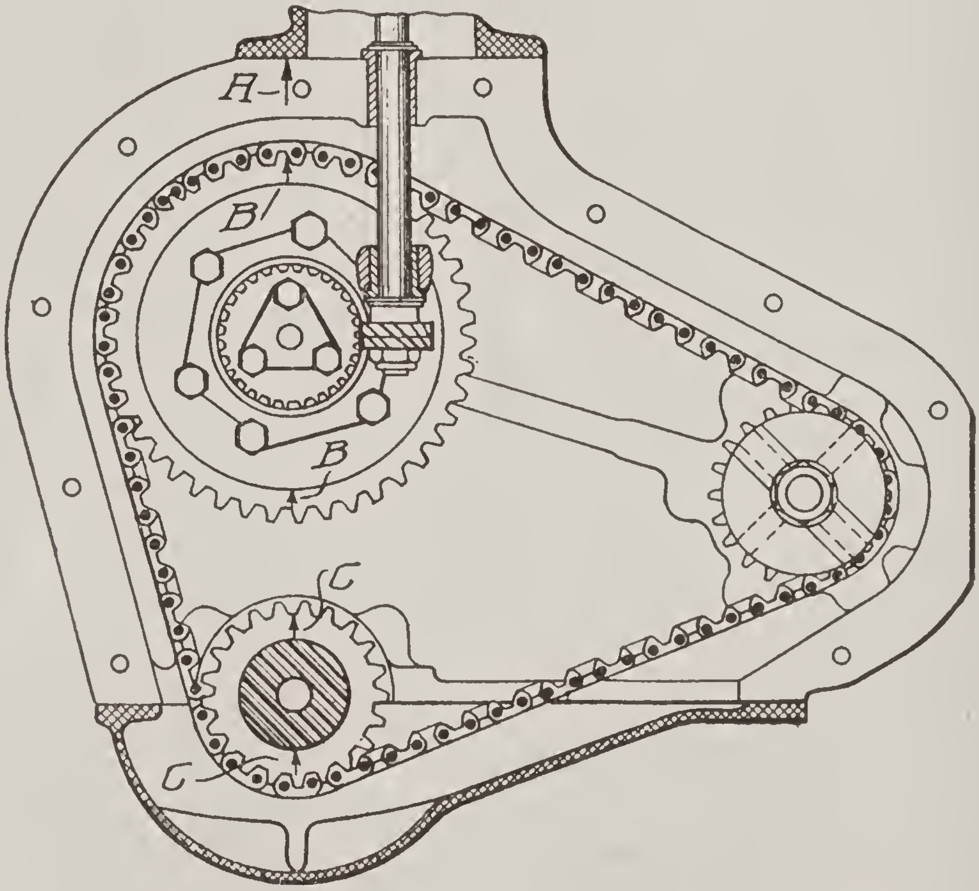


Fig. 180. Silent-Chain Drive for Packard Twelve, Showing Method of Marking

that just illustrated and described; it allows the placing of the camshaft and other shafts anywhere desired (at least in so far as the gear is concerned); it is more quiet than the gear drive in the prescribed position which the two-to-one reduction necessitates; it is less expensive to construct and apply, and it weighs slightly less. The teeth on the silent-chain gearing are called sprocket teeth, while those on the two-to-one reduction are called gear teeth.

In the silent-chain drive for camshaft and accessories, which is shown in Fig. 180, it will be noted that there is a line scribed vertically across both gears and the crankcase, with prick-punch marks on the case at *A*, on the camshaft sprocket at *BB*, and on the crankshaft sprocket at *CC*. This makes its correct adjustment easy. A straightedge is laid across the case marks, the crankshaft sprocket turned to this line, and the chain put in place but not joined; finally the camshaft sprocket is turned to the line, the chain moved to hold it in this position, and its ends joined. By this method, there would be two possible positions for the camshaft sprocket, as compared with the crankshaft sprocket and line on the case. These could readily be distinguished as correct and incorrect as soon as the chain is applied and the engine given a couple of turns. If incorrect, it is simply a matter of lining them up again by opening the chain, turning the camshaft gear through 180 degrees, putting the chain back on and joining its ends a second time.

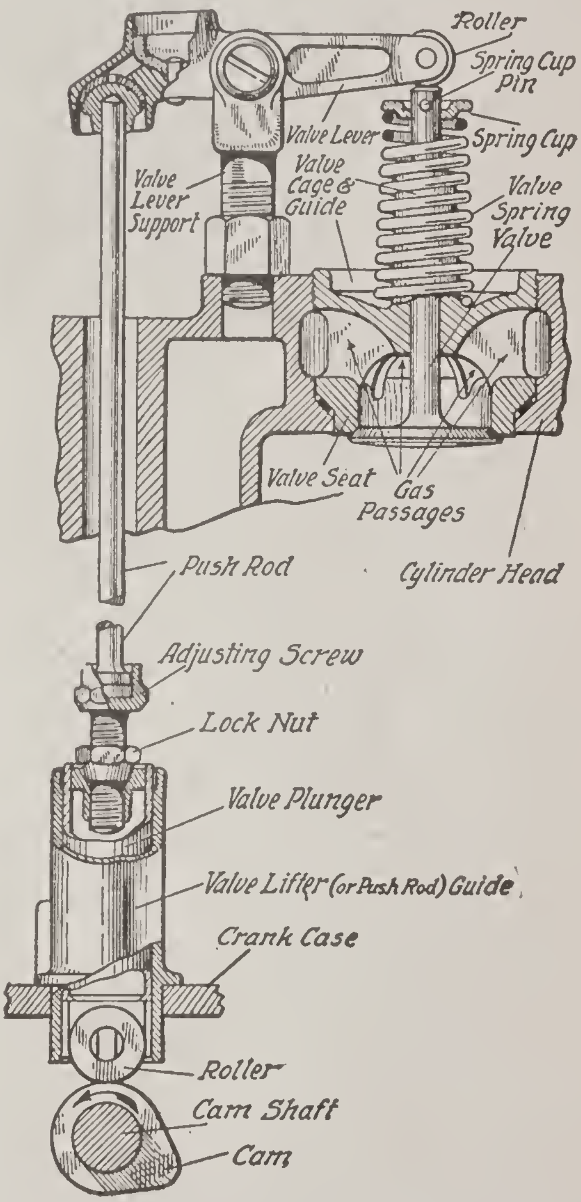


Fig. 181. Typical Overhead-Valve Layout, Showing Complete Mechanism

Other Parts of Valve System. There are a number of other parts in the valve group whose names and functions should be explained, for these are of interest to both the owner and the repair man. The repair man should know what work they do in order to be able to repair them successfully. Fig. 181 shows an overhead-valve system in which the camshaft is in the usual place in the crankcase; long push rods are used with rocker arms, or levers, at the top. This is mentioned because many, in fact the majority of, motors with overhead valves have an overhead camshaft like the Chalmers, Fig. 156.

In this figure the various parts are named. The rotation of the *camshaft* brings the *cam* around so that it lifts the *roller* and *plunger* which has the *adjusting screw* and its *lock nut* at the top. The top of the roller bears against the bottom of the *push rod*, and the upper end of the push rod operates the *valve rocker lever* which is held in the support. At the other end of the valve rocker lever a *roller* presses against the top end of the *valve stem* and pushes it down from off the *valve seat* against the pressure of the *spring*, the upper end of which is held by the *cup* and *cup pin* and the lower end rests upon the upper surface of the *valve cage.* The latter is made so that its central upward extension also forms the *valve guide.* The valve cage is screwed down into the *cylinder head* with packing to make a gas-tight joint. It carries the *valve seat* and is cored out for the *gas passages* through which the gas enters (or leaves).

When the valve in pockets is substituted for the long push rod, in either the **L**-head or in the **T**-head cylinder, the construction is about the same as if the upper right-hand valve group were lifted bodily, turned upside down, and placed so that the upper end of the valve stem, upon which the roller rests, comes into contact with the adjusting screw. In that case, the valve lifter would be called the push rod, and the valve cage would become a part of the cylinder with an integral or, in some cases, a removable valve guide.

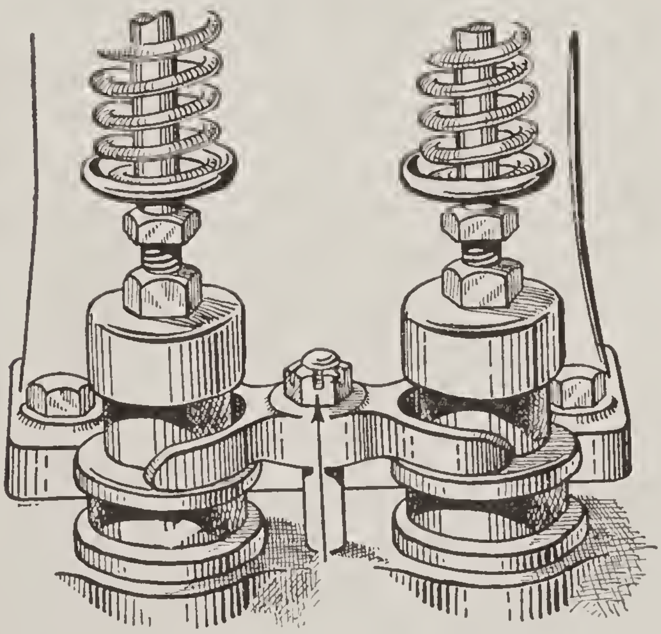


Fig. 182. Method of Holding Two Push Rods with Yoke and Single Central Nut

Push Rods and Guides. As can be seen from Fig. 181 and the explanation accompanying it, the push rod and its guide, or lifter and guide, become important. The shape of the cam is such that it deals the roller and lower end of the push rod, or lifter which holds it, a fairly heavy blow sideways each time it comes against it. If the roller and rod are not a perfect fit, something will yield each time, and the roller will wear oval in a short time. The movement and noise will increase rapidly and soon become very objectionable. The only remedy is replacement. These guides are held in place in one of two ways; either individually by means of a pair of bolts or in pairs by means of a yoke and a single central bolt and nut of large diameter. The Locomobile, Fig. 151, shows the former method; the Haynes, Fig. 152, the latter method. These, however, are end views which do not bring out the point as clearly as Fig. 182. Here the arrow points to the nut midway between the two push rods, which holds down the yoke that rests upon shoulders on the push rods and holds them in place. From a repair man's point of view, the latter construction is better, for the push rods can be removed and replaced much more easily and quickly.

Valve Cage Repairs. When the valves are in overhead cages, it is highly important that they fit tightly in the cylinder head; they must be ground in as carefully and as tightly as the valves are ground into their seats. Where a shop handles a good many motors of the overhead-valve type, it is desirable to make a rig to do the grinding easily. One of these rigs is shown in Fig. 183. It consists of a shaft and handle with lock nuts for the valve cages used on Buick cars. On these cars, it is in two parts; the cage proper, and the locking member which screws into the cylinder. Obviously the cage is the one to be ground in. The rig shown slides in the central opening, that is, fits in the valve guide, and has a lock nut top and bottom to fasten it tightly. When fitted into place firmly, the right-angle bend in the rig gives a handle by means of which the cage can be lifted in and out and, what is more important, rotated on its seat. When the cage is prepared, the seat is given a little oil and emery or oil and powdered glass or prepared valve grinding composition, the cage is set in place and ground in the same as a valve, that is, with one-third to one-half rotations in one position, then lift, move around, and repeat in the new position, continuing this until the whole surface of the cage in the cylinder has been covered twice. This should result in a good seat.

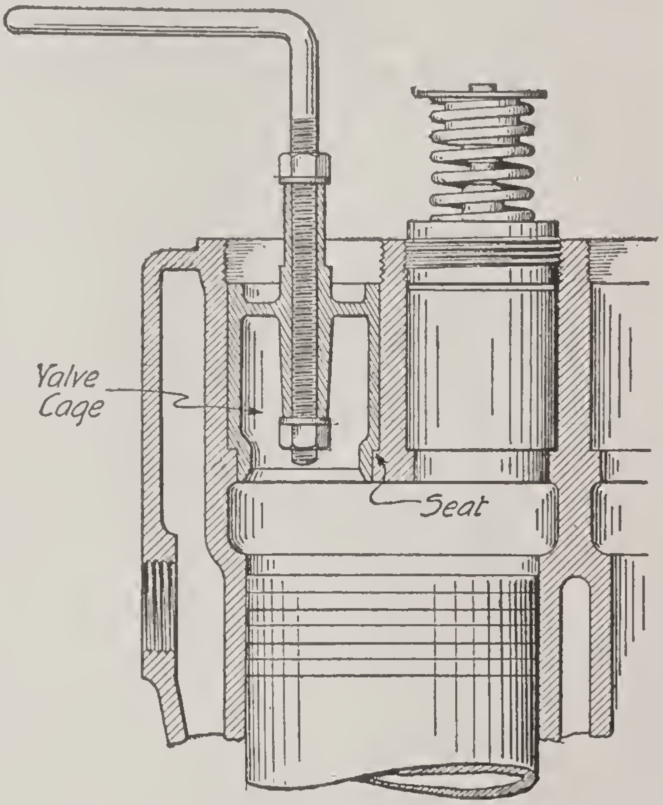


Fig. 183. Simple Fixture for Grinding-In Overhead Valve Cages
Courtesy of "Motor World"

When the valves in an overhead motor need grinding, the valve and cage are taken out completely and held in an inverted position in a vise or other clamp, and the valve ground in to the seat in the cage in the regular way. It is said this can be done very rapidly and well by chucking the valve stem, as it projects from the cage, in a lathe rotating at a very slow speed, and operating the cage by hand, that is, slide the cage back, apply grinding compound, then move the cage up to the rotating valve and hold it with the hand while the valve is turning with the lathe. In holding it thus, the pressure endwise should be very light.

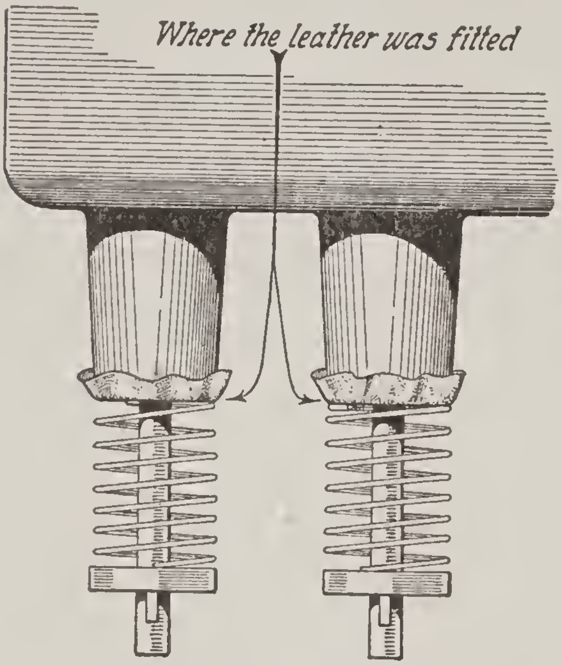


Fig. 184. Method of Curing Valve-Guide Leak Quickly and Cheaply

Valve Guides. The valve stem must be a tight fit in the guide, otherwise air will leak through into the combustion chamber and dilute the mixture, or the compression will leak out, or both. Any valve leak will affect the running of the motor, so it should be stopped at once. Two methods of temporarily remedying small leaks are shown in Figs. 184 and 185. A simple leather washer with a small hole through the center, which fits tightly over the valve stem, is pressed up around the outside of the guides, as shown in Fig. 184. This simple repair was very effective, and the leather washers lasted an astonishingly long time. The other method, Fig. 185, shows practically the same result arrived at differently. In this case, old spark-plug shells, with considerable recesses in the center part, were turned down so as to fit around the bottom of the guides. These recesses were packed with felt or other available packing, care being taken to pack the recesses tightly. Then the whole thing was held up in place by a lighter spring put inside the main valve spring. By adding a few drops of oil to the packing now and then to keep it soft, it lasts almost indefinitely.

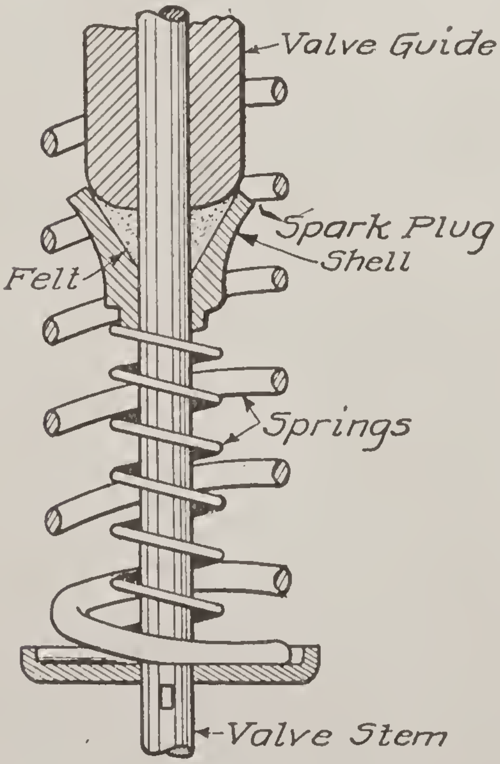


Fig. 185. Remedy for Leaky Valve-Stem Guide, Using Old Spark Plug and Felt

The valve-guide hole in the cylinder is generally made as long as possible, both to give a straight and true hold on the valve stem and thus maintain its straightness in spite of the heat, and to give a long wearing surface. This length and the need for accuracy throughout makes the valve-guide hole an awkward surface to repair. When worn beyond any hope of simple repair, it is best to ream it out and press in a bronze bushing so that the valves can still be used. An excellent tool for this purpose, developed for Dodge motors but which is usable for almost any motor, is shown in Fig. 186. This consists of a high threaded bushing which is clamped to two diagonal cylinder studs. The thread inside the bushing is very fine. A long tube, with the lower end bored out to take a standard reamer, is screwed into it. The top is squared and a handle is made to fit it. When the handle is turned, the tube is gradually screwed down into the cylinder, carrying the reamer slowly but truly down through the valve guide. This rigging is simple, easily made, and gives accurate results. When the valve-guide hole is reamed, the bushing can be turned up and pressed in with any form of shop press.

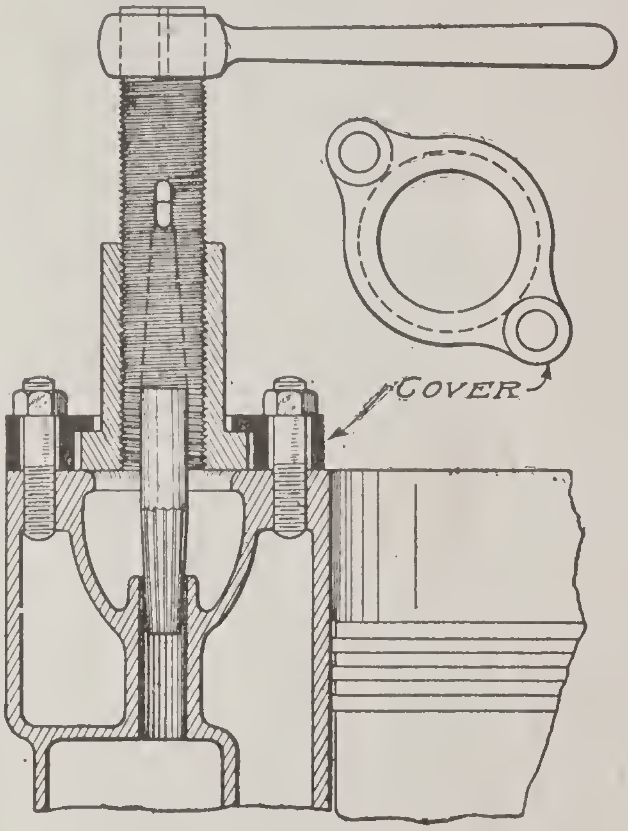


Fig. 186. Rigging for Reaming Out Valve-Stem Guide Holes
Courtesy of "Motor World"

Valve Caps. The plug which fits into the top opening in the cylinder through which the valve is put in place and removed is called the valve cap. Sometimes it has external hexagonal sides so it can be easily removed, but more often it has an internal hexagon, or internal ribs. The latter form can be removed most easily by constructing a special tool, consisting of a cylindrical member, with a bottom diameter slightly larger than the opening in the valve cap, with four (or more) teeth, or projections, set into the bottom of this to match the ribs inside the cap. A central hole is drilled for a bolt with spark-plug threads at the bottom. To use the member, remove the spark plug, set the device in place, slip the central bolt in and screw it down into the plug to hold the whole thing in place, then apply a wrench to its upper square surface and remove the valve, cap and all.

It can be laid aside just as removed, and when the work is concluded, the whole thing can be screwed back in, the central screw loosened, and the rig removed from the cap.

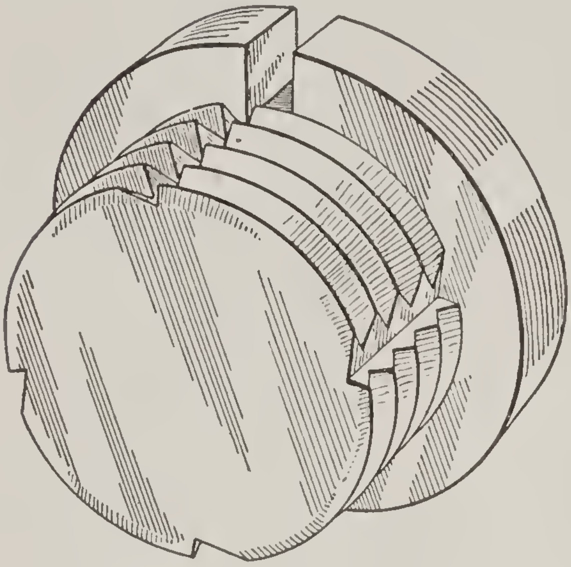


Fig. 187. Reamer for Clearing Out Threads of Valve Cap
Courtesy of "Motor World"

Sometimes the threads in the cylinder into which the valve cap screws become dirty, slightly cut up, or marred so that the cap does not screw in or out readily. By taking an old valve cap of the same motor and same threads and fluting these in a milling machine, as indicated in Fig. 187, a neat tap can be made which will clean out the threads in a jiffy. It is simple, effective, and cheap.

Cleaning Camshaft Gears. On the majority of engines, the camshaft and other gears or the silent chain which replaces them, are lubricated automatically by the running of the engine as they are by-passed in on the engine lubricating system. This is an excellent feature, but it leads to neglect. These gears or sprockets are sure to wear, and the metal worn off remains in the case. Moreover, dust and the impurities of the oil are bound to get in. The foreign matter has a cutting action on gears, chains, or bearings, so the gear case should be cleaned out frequently. This is done best by thoroughly flushing out the case and the gears, or sprockets and chains, as the case may be, with kerosene. After using the kerosene, use gasoline along with the kerosene to clear away any remaining dirt or oil. After applying the gasoline, wait long enough for it to evaporate before replacing the parts. while it might be considered extravagant to use both, it really is economical of time.

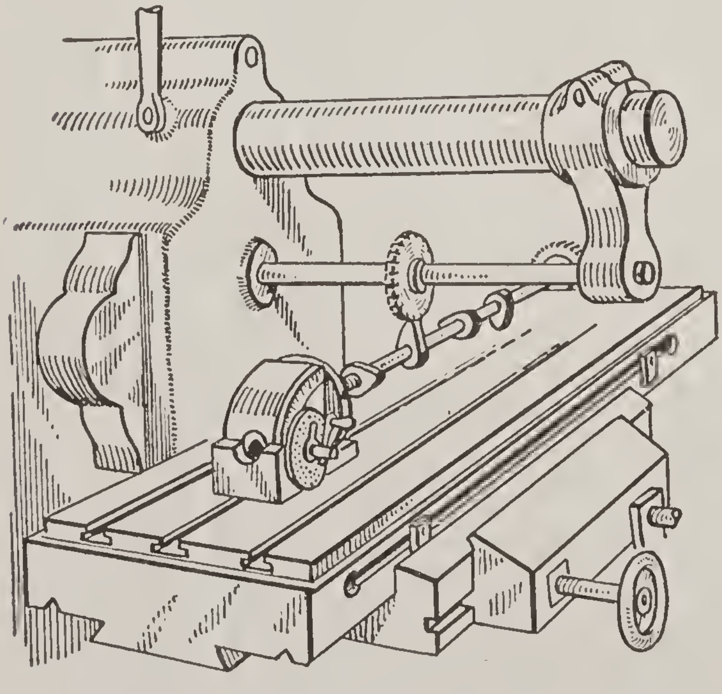


Fig. 188. Checking up Camshaft in Milling Machine

Twisted Camshafts. With the present form of camshaft having the cams forged integral, troubles and irregularities between one cylinder and another, which the repair man finds difficult to trace or run down, sometimes develop in the running of the engine. A fairly light camshaft will sometimes become twisted, usually right at a cam where the stress is. When trouble of this kind is indicated, the camshaft should be removed and tested. A good way to do this is to place the shaft in the milling machine with the index head set so that one revolution of the shaft can be divided into four equal parts. Place a thin disc in the arbor, then mount the shaft and bring it up to the disc. Choose one of the cams and set the disc to the exact center of the point of it. Then, by turning the shaft a quarter-turn each time, the other cams can be tested with their relation to this one. Sometimes a difference of $\frac{1}{8}$ inch will be found in this way. The lay-out for this is seen in Fig. 188.

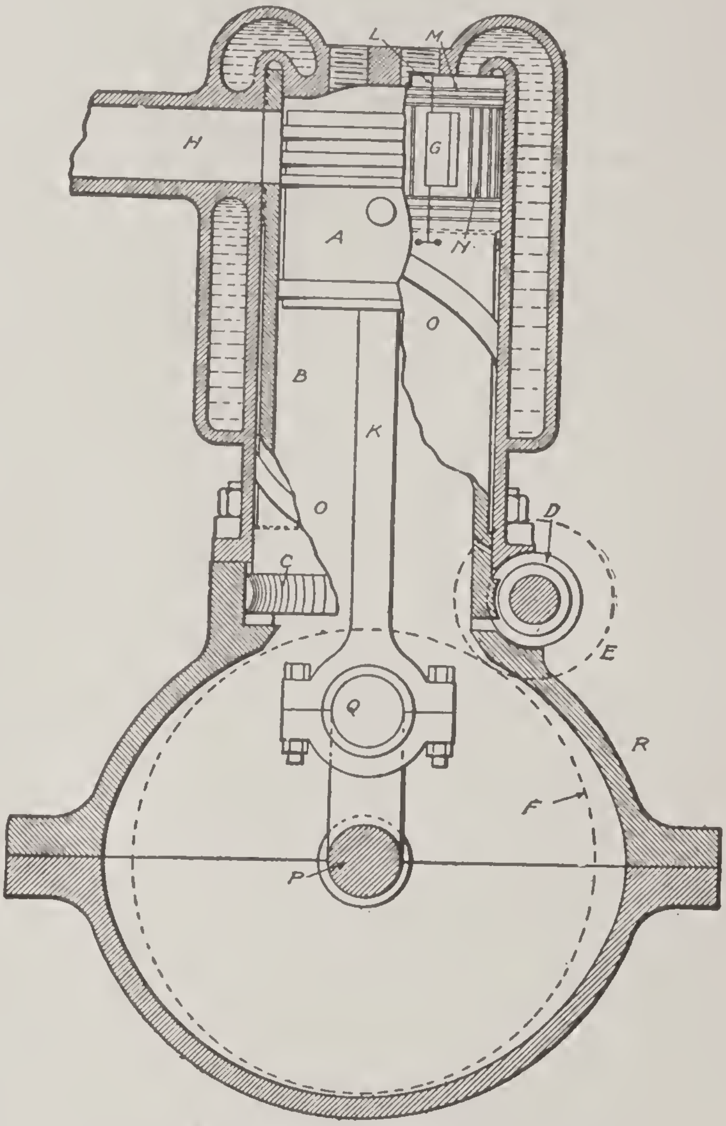


Fig. 189. Section through Ledru (French) Camless Engine. The Rotary Gear-Driven Sleeve Displaces All Cams

DETAILS OF SLIDING-SLEEVE VALVES

A method of avoiding cams, and with them all cam troubles, is the use of a sliding sleeve in place of a valve, slots in the sleeve corresponding to the usual valve openings, both as to area and timing. The sleeves may be operated by means of eccentrics by various lever motions, or by a direct drive by means of agear mounted on a separate shaft.

Gear Control. An example of the application of a worm and gear for this purpose to a French two-cycle engine is shown in

Fig. 189, although there is nothing in its construction which would prevent its use on the more usual four-cycle engine.

In this figure, *P* is the usual crankshaft, *Q* the large end of the connecting rod *K*, while *A* is the piston and *R* the crankcase, no one of these differing from those in other engines. On the crankshaft there is a large gear *F*, which drives a smaller gear *E*, located on a longitudinal shaft above and outside of the crankcase. On this shaft is located a worm gear *D*, which meshes with a worm *C* formed integral with the sleeve surrounding the piston *B*. Aside from this worm gear, the sleeve is perfectly cylindrical, being open at both ends. It is placed outside of the piston, between that and the cylinder walls. At its upper end, it has a number of ports, or slots, cut through it, which are correctly located vertically to register, or coincide, with the port openings in the cylinder wall when the sleeve is rotated. One of these is seen at *H;* the exhaust, while 90 degrees around from it, and hence invisible in this figure, is a similar port for the inlet. As the crankshaft rotates, the side shaft carrying the worm is constrained to turn also. This turns the worm which rotates the worm wheel on the sleeve. In this way, the openings in the sleeve are brought around to the proper openings in the cylinder, and the combustion chamber is supplied with fresh gas, the burned gases being carried away at the correct time in the cycle of operations.

With a motor of this sort, the greatest question is that of lubrication. The manner in which it is effected in this case is by means of the large wide spiral grooves shown at *OO* and the smaller circular grooves at the upper end *M*. Another method which renders this problem more easy of solution is by the machining of the sleeve; during this operation much metal is cut away along the sides so that the sleeve does not bear against the cylinder walls along its whole length but only for a short length at the top and a still shorter length at the bottom.

Knight Sleeve Valves. In the last few years, tremendous progress has been made here and abroad with the Knight motor, named after its Chicago inventor. In many important factories this valve has displaced the poppet valve. In a regular four-cylinder four-cycle engine, the valves consist of a pair of concentric sleeves, the openings in the two sleeves performing the requisite functions of valves in the proper order. These sleeves, as Fig. 190 shows, are actuated from a regular camshaft—running at half the crankshaft speed and driven by a silent chain—by means of a series of eccentrics and connecting rods. In the figure, *A* is the inner and longer sleeve and carries the groove or projection *C* at its lower end. The collar actuating the sleeve is fixed around and into it. This collar is attached to the eccentric rod *E*, which is driven by the eccentric shaft shown. The collar *D* performs a similar function for the outer sleeve *B*.

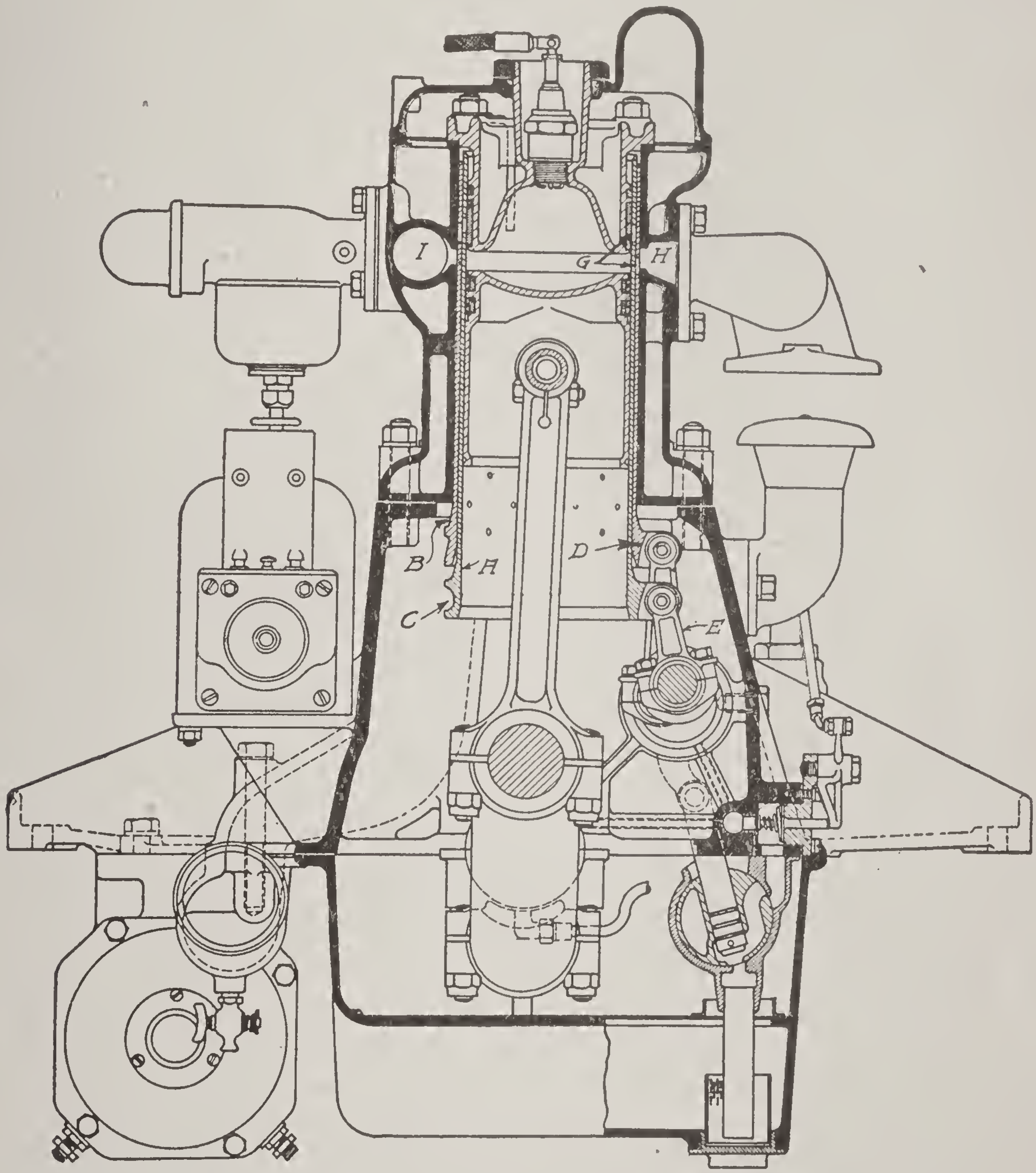


Fig. 190. Willys-Knight Engine in Which Eccentrics and Sliding Sleeves Replace Cams and Valves

At the upper ends of both sleeves, slots *G* are cut through. These slots are so sized and located as to be brought into correct

TABLE III

Royal Automobile Club's Committee Report on Knight Engine

Motor horsepower—R. A. C.		38.4	22.85
Bore and stroke		124 by 130	96 by 130
Minimum horsepower allowed		50.8	35.3
Speed on bench test		1200 r.p.m.	1400 r.p.m.
Car weight on track		3805 lb.	3332.5 lb.
Car weight on road		4085 lb.	3612.5 lb.
Duration of bench test		134 hours 15 min.	132 hours 58 min.
Penalized stops		None	None
Non-penalized stops		Five—116 min.	Two—17 min.
Light load periods		19 min.	41 min.
Average horsepower		54.3	38.83
Final bench test		5 hours 15 min.	5 hours 2 min.
Penalized stops		None	None
Light load periods		15 min.	1 min.
Average horsepower		57.25	38.96
Mileage on track		1930.5	1914.1
Mileage on road		229	229
Total time on track		45 hours 32 min.	45 hours 42 min.
Average track speed		42.4 m.p.h.	41.8 m.p.h.
Fuel per brake horsepower per hour	First bench test	.679 pt.	.739 pt.
		.613 lb.	.668 lb.
	Final bench test	.599 pt.	.749 pt.
		.541 lb.	.677 lb.
Car miles per gallon	On track	20.57	22.44
	On road	19.48	19.48
Ton miles per gallon	On track	34.94	33.37
	On road	35.97	31.19

relation to one another and to the cylinder ports and the exhaust at *H* and inlet at *I*, in the course of the stroke.

It might be thought that the sliding sleeves would eat up more power in internal friction than would be gained, but a very severe and especially thorough test of an engine of this type, made by the Royal Automobile Club of England, an unbiased body, proved that for its size the power output was greater than that of many engines of the regulation type. Moreover, the amount of lubricating oil was small.

The results of the test are shown in Table III. After the test was concluded, both the sleeves, Fig. 191, were found to show still the original marks of the lathe tool. This proved conclusively that the principle of this type was right, for the tests were equivalent to an ordinary season's running.

The slots which serve as valve ports are at *G*, Fig. 191. The longer sleeve *A* is the inner one. At the bases of the sleeves are the collars and pins *D* by which the connecting rods are attached.

The surfaces of the valves are grooved at *J* to produce proper distribution of oil.

The Knight type of motor has been adopted by a number of well-known firms in America, such as the Stearns, Willys, F. R. P., Brewster, and Moline Companies. These engines are noted for their silent running and for their efficiency. The Moline-Knight motor was subjected to a severe continuous-run test of 337 hours, under the auspices of the A. C. A. authorities, in January, 1914. During this time the motor developed an average of 38.3 brake horsepower. During the 337th hour the throttle was opened, the motor developed a higher speed and a brake horsepower of 53. After the test, the motor parts showed no particular evidence of wear. The test gives abundant evidence of the endurance and reliability of the sleeve-valve type of motor and of the sterling qualities of the product of the American automobile manufacturers.

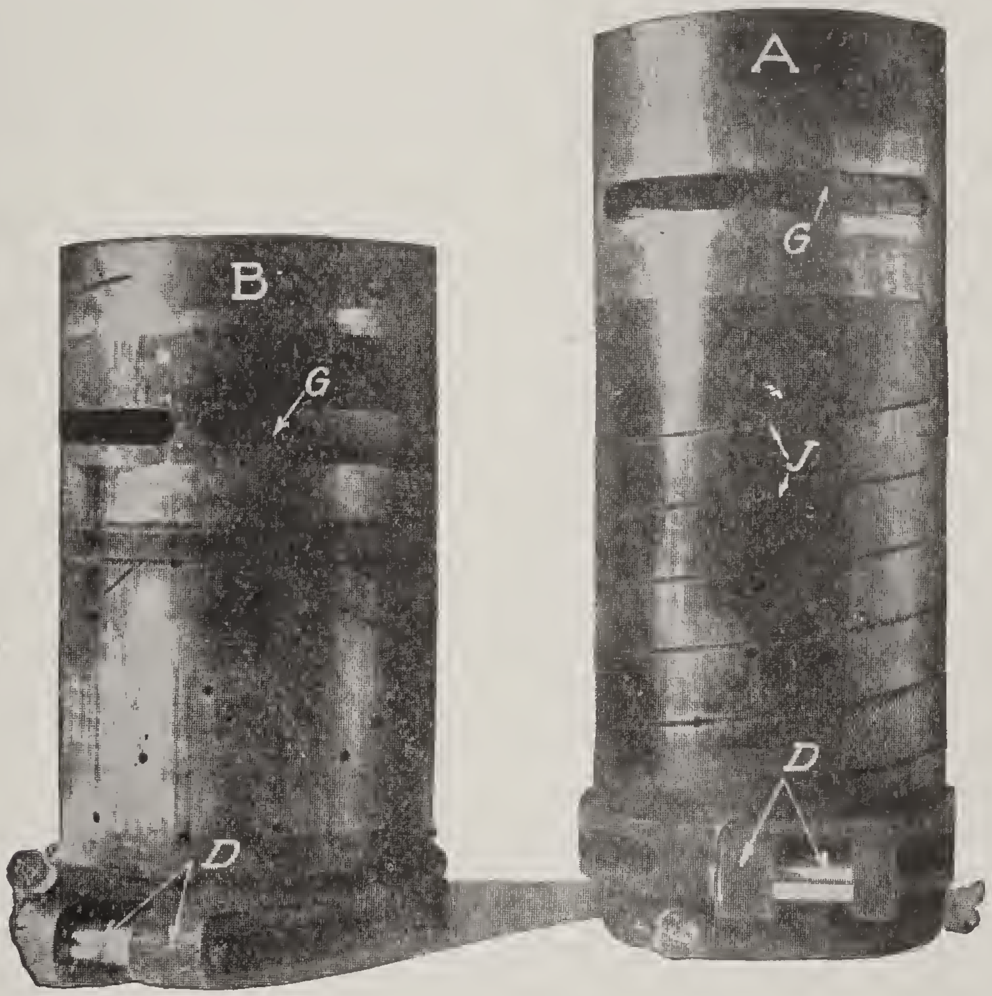


Fig. 191. Sleeves Which Replaced Valves on Knight Engine, after 137-Hour Bench Test and 2200 Miles on the Road

In addition to the four-cylinder forms just mentioned, the Knight type of motor is also made as a six, and, more recently, as a V-type eight. In these forms, the basic principle of sliding sleeves and their method of operation and timing is not changed.

Originally, the Knight motor was installed only in the highest-class cars. The firms in Europe which took it up ranked among the very first—notably the Daimler, Panhard, Minerva, etc.—but in this country it has made little progress among the better cars. It is now assuming the rank of a low- and medium-priced motor, being available for about $1000, and as an eight, for approximately $2000.

Timing the Knight Motor. While the connection between the Knight motor sleeves and eccentric rods, and between the rods and the eccentric shaft, is more or less permanent, there is the possibility of the shaft being bent or twisted during running or dismounting. The repair man should know how the motor is timed, in order to correct any faults. As will be noted in the timing diagram shown in Fig. 192, this is not radically different from the poppet-valve type. The inlet opens at 6½ degrees past the upper center and closes 45 degrees past the lower center, a total opening of 218½ degrees. The exhaust opens 40 degrees before the lower center and closes 5 degrees past the upper center, a total opening of 225 degrees.

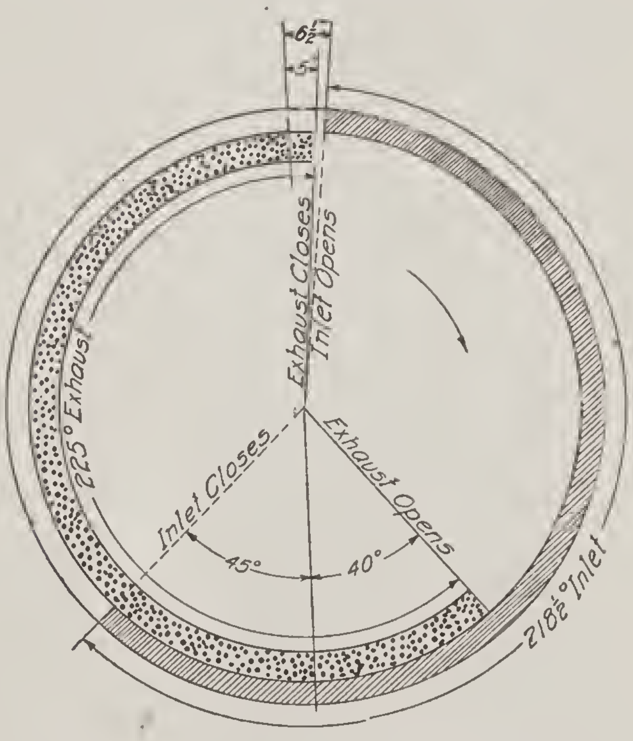
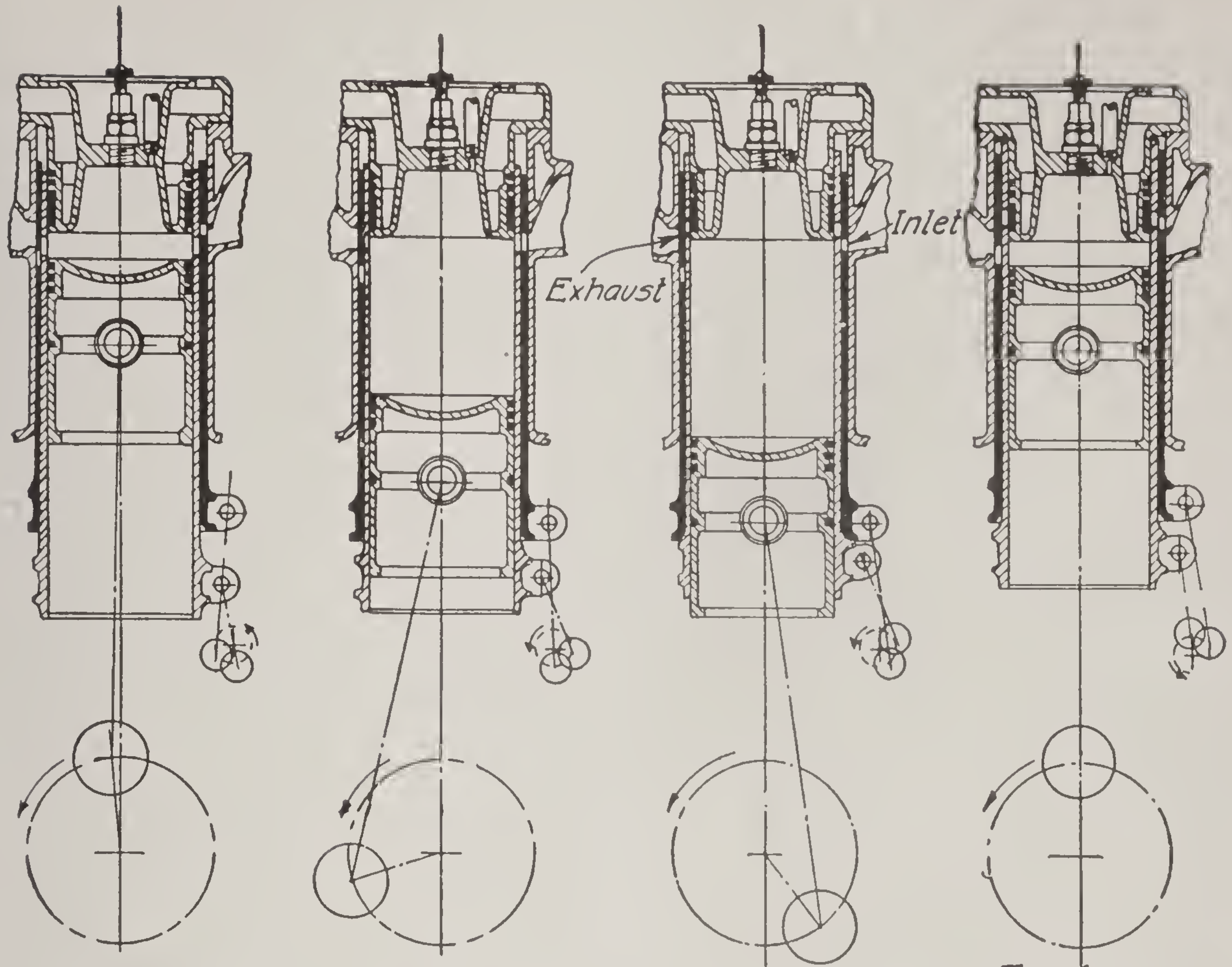


Fig. 192. Timing Diagram for Knight Sliding-Sleeve Valve Motor

The various positions are clearly shown in Fig. 193, and make the action of the motor much more clear than the simple timing diagram. The figures, reading from the left, are as follows: *1* shows the inlet just beginning to open; the inner sleeve is coming up, and the outer sleeve is going down, so the port opening is increasing in area with unusual rapidity. At *2* the inlet is fully open; the inner sleeve is coming up, but the outer has reached the bottom of its travel; the two ports are fully open and register exactly with one another and with the opening in the cylinder. At *3* the inlet has just closed, the inner sleeve is still coming up, while the outer sleeve has come up a considerable distance. A slightly further upward movement of both inner and outer sleeves shows the motor in *4*, the top of the compression stroke, with all ports closed. This is the point of explosion. In *5* the exhaust

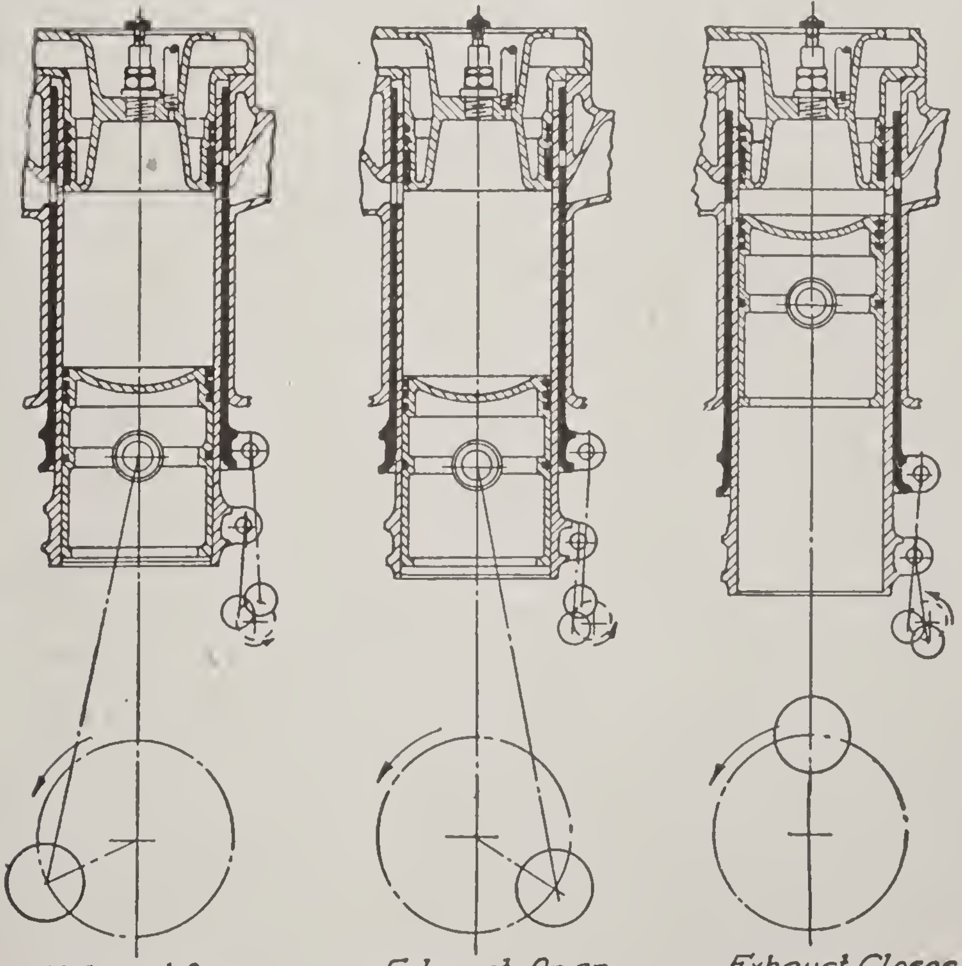


Inlet Opens
Position 1

Inlet Open
Position 2

Inlet Closes
Position 3

Top of
Compression Stroke.
Position 4



Exhaust Opens
Position 5

Exhaust Open
Position 6

Exhaust Closes
Position 7

Fig. 193. Various Stages in Cycle of Knight Sliding-Sleeve Motor

is beginning to open, the inner sleeve has reached the top of its movement and started down, while the outer is almost at the top. At *6* the exhaust port is fully open, the slots register exactly with each other and with the cylinder outlet, both sleeves are traveling down, the outer having reached and passed its highest point. At *7* the exhaust has just closed, the inner sleeve has reached its bottom position and is about to start up, while the outer sleeve is close to the bottom. The cycle of inlet, compression, explosion, and exhaust has now been completed and is about to start over. Note that position *7* is almost exactly like position *1*, but a slight additional movement of the sleeves is needed to produce the latter.

The eccentric rods are very similar to connecting rods, as will be noted by referring back to Fig. 191. Here *E* is the eccentric rod operating the inner sleeve *C*, while *D* is the eccentric rod which operates the outer sleeve *B*. As will be seen, these have an upper end exactly like a piston, or wrist pin, except that no bushing is provided. At the lower end, it will be noted that the fastening and arrangement is just like the big end of a connecting rod. It should be cared for, adjusted, and tightened in just the same way to get the best results.

DETAILS OF ROTATING VALVES

Successful Operation Requires Two Valves. In addition to rotating and reciprocating sleeves and reciprocating valves, the rotating valve has been tried, in common with any number of other devices intended to supplant the ordinary poppet valve. This arrangement on a multi-cylinder motor consisted of a single valve for all the cylinders, which extends along the top or side of the cylinder head and is driven by shaft, chain, or otherwise, at one end. Naturally, this necessitated having the ports cut very accurately in the exterior of the valve, or rather the sleeve—as it usually assumed the form of a hollow shell—for not alone did it act as inlet and exhaust manifold but also as the timing device. This multiplicity of functions seems to have been its undoing, for the latest types using valves of this form have no longer one shell as at first but a pair, one for the exhaust valves and one for the inlet valves. In the latter shape these have been more successful, but not sufficiently so to bring them into competition with the poppet and Knight sleeve-valve forms.

Roberts Rotary Valve. A motor—a two-cycle motor, by the way—which has been very successful in motor-boat and aeroplane work, although not much used for motor cars, is the Roberts, shown in Fig. 194, with the valve in Fig. 195. This valve is for the inlet ports only and is located inside the crankcase, while the cylinders exhaust freely into the open air, the exhaust issuing directly from the cylinders.

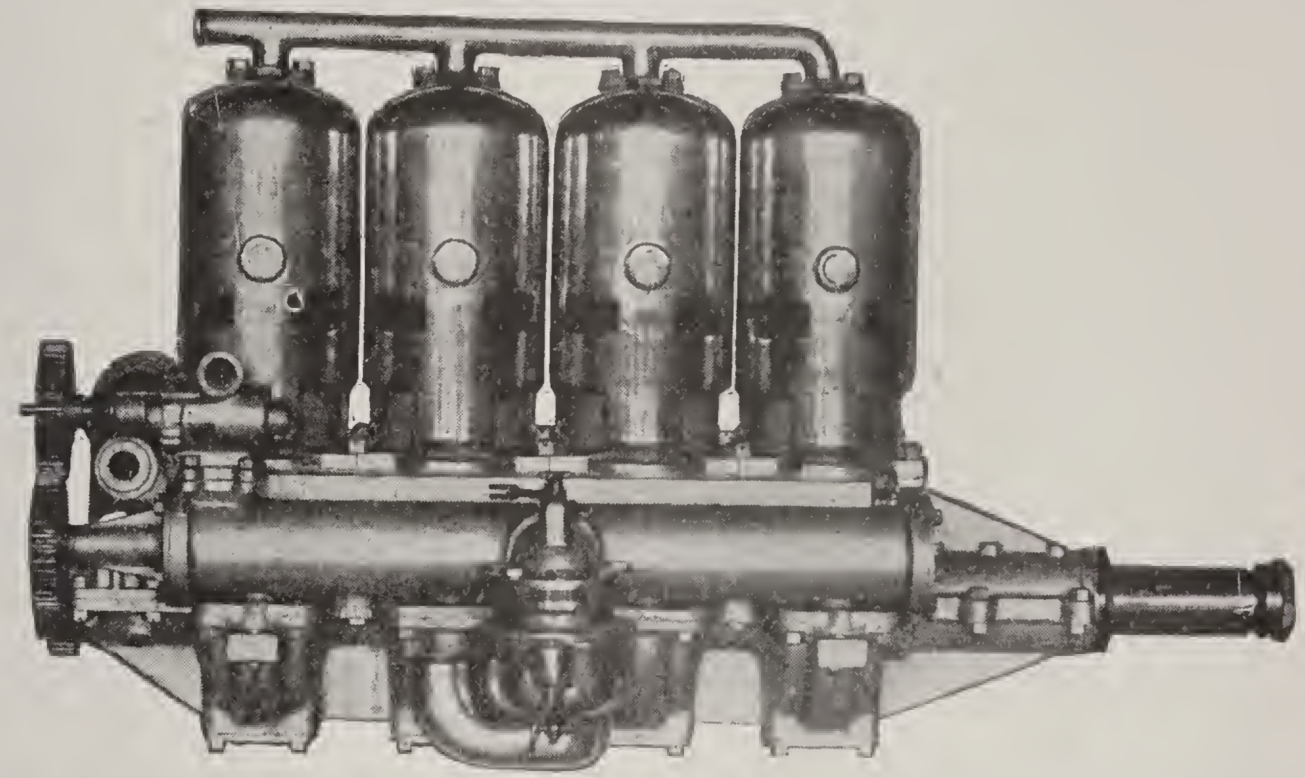


Fig. 194. Roberts Two-Cycle Motor with Rotating Crankcase Valve
Courtesy of E. W. Roberts, Sandusky, Ohio

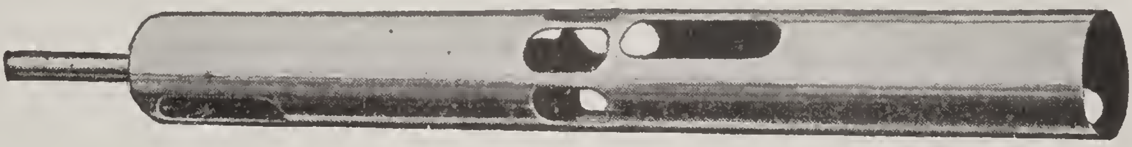


Fig. 195. Rotating Inlet Valve of Roberts Two-Cycle Motor

EXHAUST SYSTEM

Importance of Handling Exhaust Gases Properly. In all that has been said previously on the subject of valves no mention has been made of a specific form of valve, everything applying equally to the inlet or the exhaust type. Under the subject of carburetors, the inlet manifold has been considered in detail. So far, nothing has been said of the exhaust gases and the method of handling them. Generally speaking, the matter of handling exhaust gases in the past has been done with the smallest possible amount of time, trouble, and thought. They had to be gotten rid of, so it was done as easily and quickly as possible. As engines got larger and larger, and as speeds increased, there was more and more gas to handle. The growing cry for a quiet or a noiseless car necessitated giving the problem more thought, for the simple application of a muffler did not entirely eliminate the noise. As fuels grew heavier, heat was required to assist in the process of vaporizing. In order to apply heat, many designers began to see possible uses for some of the gas pouring out at the rear end of the car. Today, the handling of the exhaust gases is probably being given as much thought as any part or unit on the entire car.

Forms of Exhaust Manifolds. Ordinarily the exhaust gases emerge from the cylinders into the exhaust manifold. This is generally a cast-iron member of fairly large size held in position by bolts. At its rear end, which is round, it is threaded or flanged for the attachment of the exhaust pipe. This is shown rather well in the National engine in Fig. 196. Although this is a twelve-cylinder motor, it

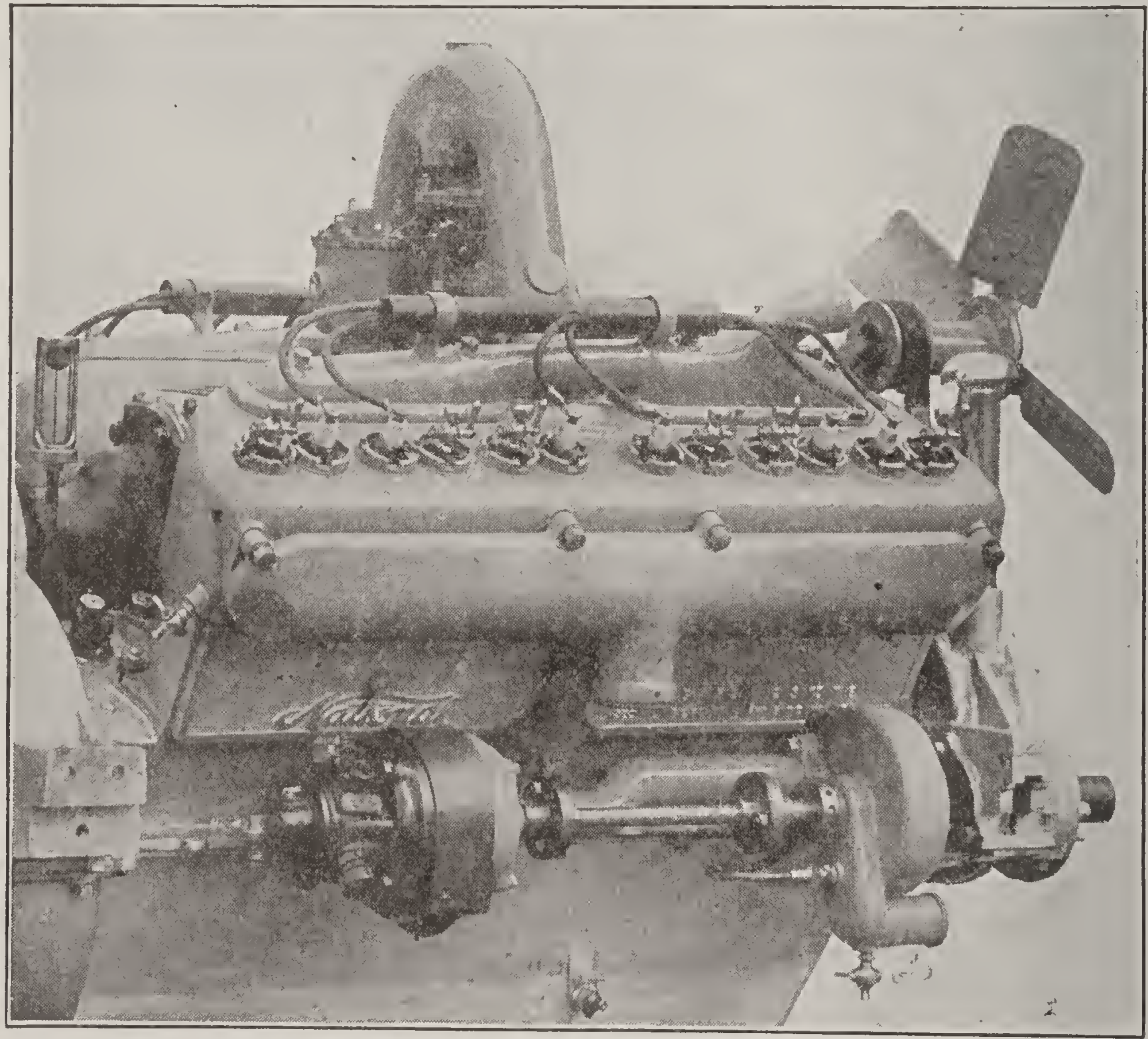


Fig. 196. View of National Twelve-Cylinder Motor, Showing Particularly Exhaust Manifold
Courtesy of National Motor Vehicle Company, Indianapolis, Indiana

has the outside valves, so the exhaust manifold is located there. It is a typical cast-iron manifold, differing from the ordinary manifold only in having the outlet at the center instead of the rear end. Six bolts hold it in place; four on the upper edge, and two on the lower. Its interior structure is evidently the same throughout, and no special provision has been made for reducing gas friction. It has no attachments of any kind.

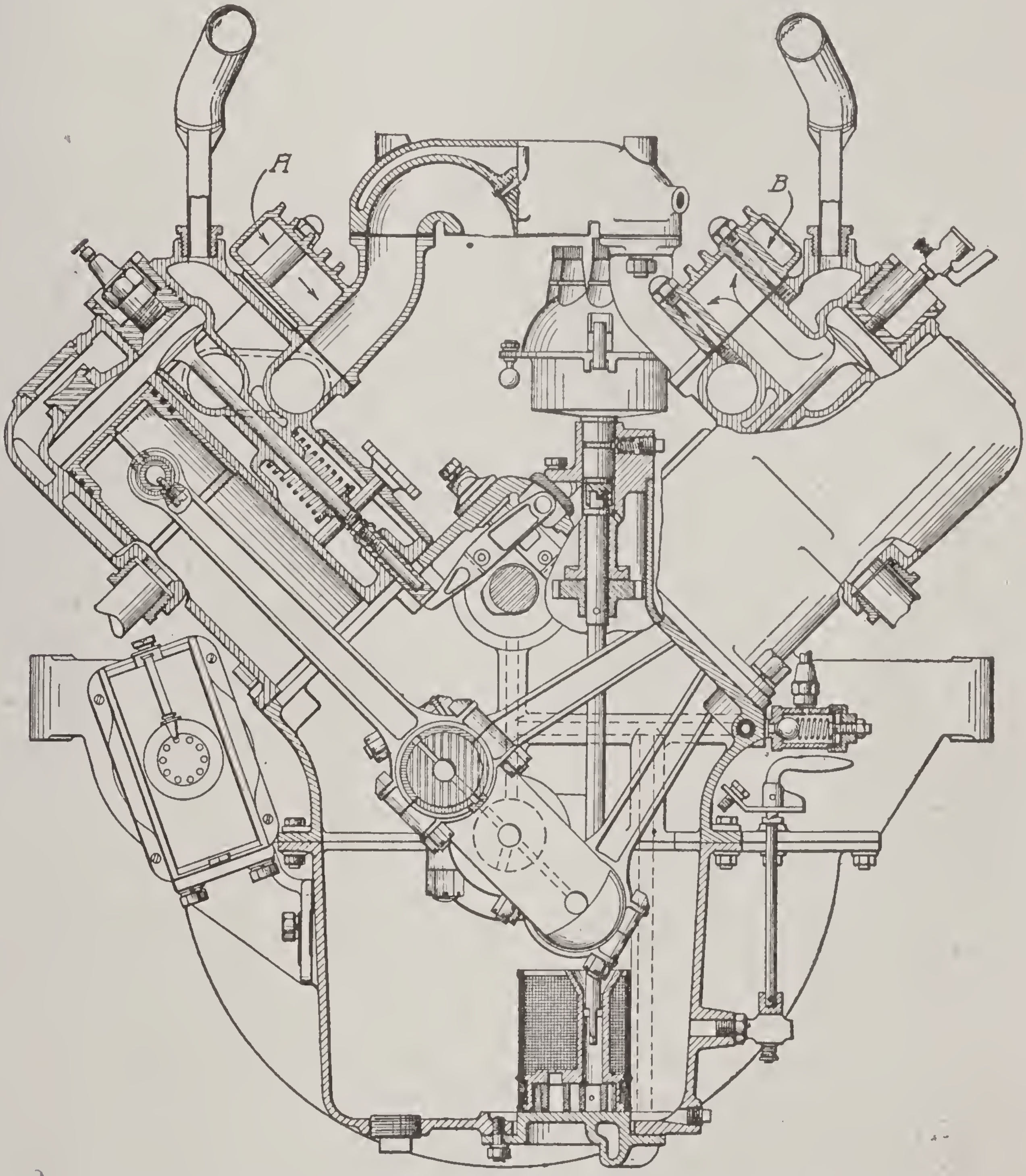


Fig. 197. Section through Peerless Eight, Showing Ribbed Exhaust Manifold
Courtesy of Peerless Motor Car and Truck Corporation, Cleveland, Ohio

Many exhaust manifolds have been cast integral with the cylinder block; this method is quite popular among small car makers, as it is used as much to save the expense of machining and fitting and to reduce the weight and number of parts as for any other reasons. In the larger sizes it probably never will become popular, because of the difficult core work in the foundry which makes cylinder-casting cost prohibitive, and thus more than offsets any other saving.

A number of manifolds have been cast with cooling fins, or flanges, on the outside, the effect being to reduce the exhaust heat immediately by dissipation; a secondary idea is that of making the casting stiffer and stronger and less liable to loss by breakage. A flanged manifold is shown in Fig. 197, which illustrates the Peerless eight-cylinder motor; the exhaust manifold is marked at *A* and *B*. The section taken at *A* shows the full exterior size; the boss, through which a holding bolt passes, is seen in elevation. At *B*, however, the section is taken through a pair of bolts, so the section appears smaller than it actually is.

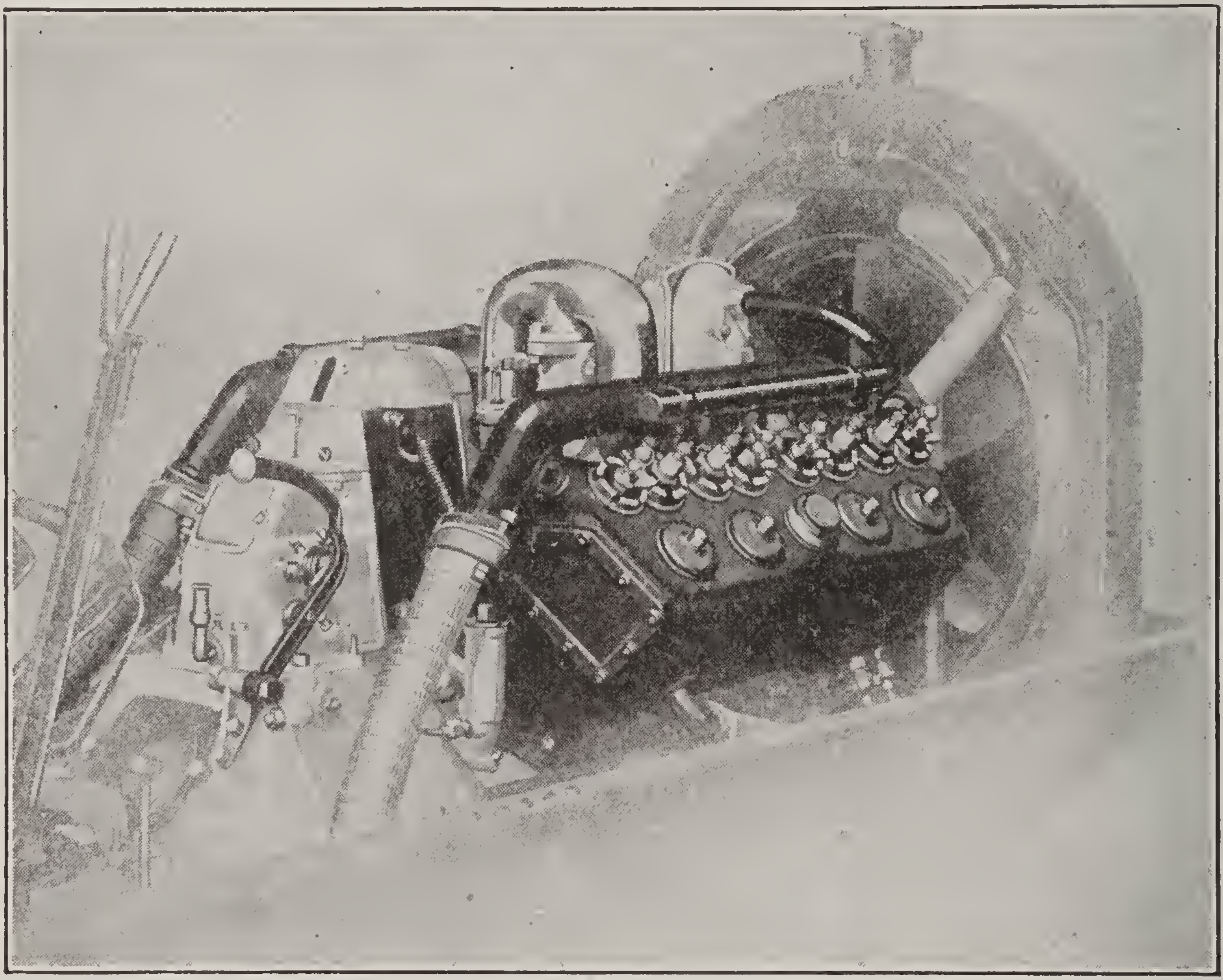


Fig. 198. Three-Quarter Rear View of Cadillac Motor in Chassis, Showing Exhaust Manifold and Pipes in Duplicate

In the usual eight- and twelve-cylinder motor and in some sixes, a pair of manifolds, each with its own exhaust pipe and muffler, are used. It has been found by experience that the tremendous volume

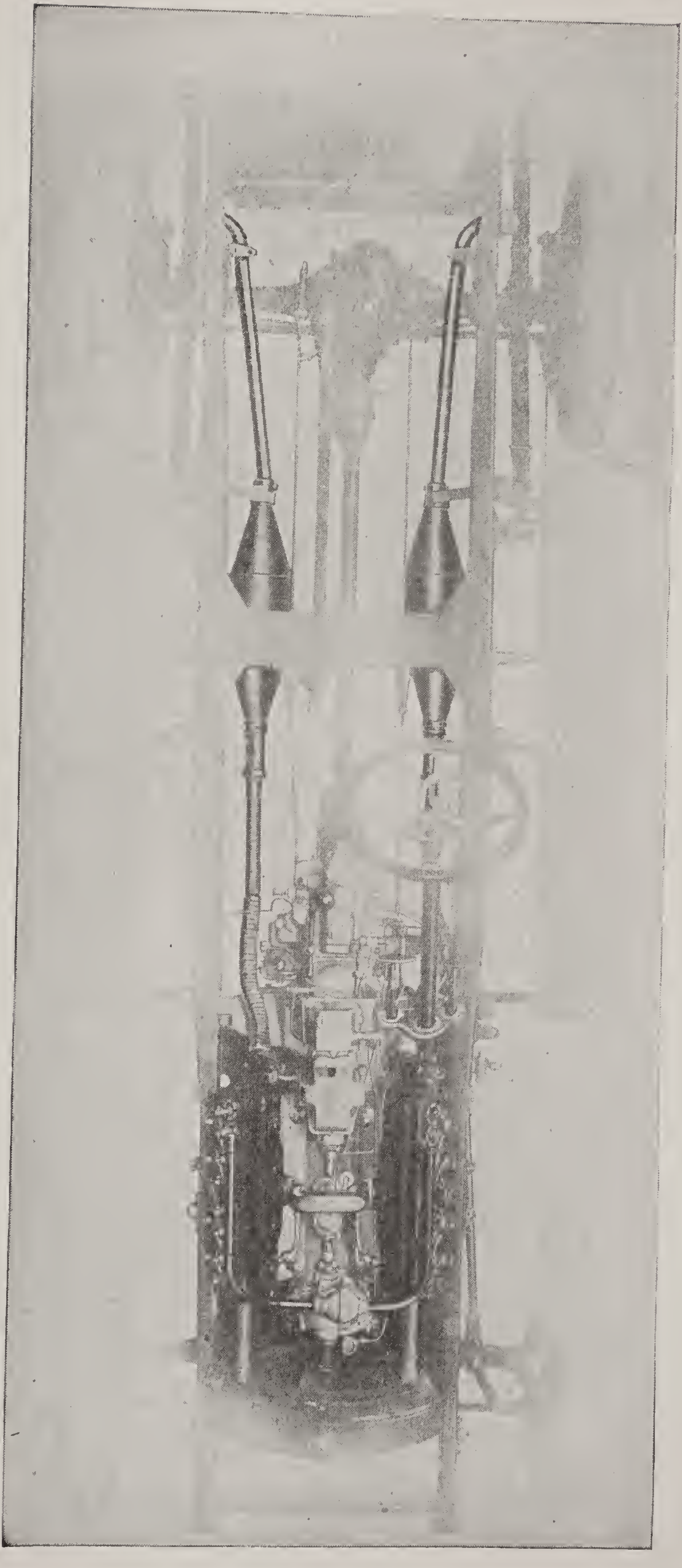


Fig. 199. Cadillac Chassis from Above, Showing Double System of Exhausting with Twin Mufflers

of gas to be handled, the speed at which it had to be handled, and the necessity for silence called for a separate exhausting system for each group of cylinders. These were problems, aside from the fact that it was more simple structurally to handle the exhaust in two manifolds. A double-manifold construction is shown in the Cadillac, Fig. 198, which is a view of the rear end of the engine. The two manifolds for the two sides can be seen readily; also the two separate exhaust pipes, wrapped with asbestos where they pass the dash and other wooden parts. A further view of this car is shown in Fig. 199, the chassis from above, in which the two separate systems can be followed back to the mufflers just forward of the rear axle on either side.

Muffler. The purpose of the muffler is to reduce the pressure of the gases by expansion to a point where they will emerge into the atmosphere without noise. This is generally done by providing a number of concentric chambers; the gas is allowed to expand from the first passage into the much larger second one, then into the still larger third one, and so on, to the final and largest passage, which is connected to the pipe leading out into the atmosphere. This is not as simple as it sounds, for, if it is not well and wisely done, there will be back pressure which will reduce the power and speed of the engine, cause heating troubles, and may possibly cause the motor to stop.

The process of spraying water into the muffler has been tried, but on account of its first cost and lack of positive beneficial results, it has been abandoned. The actual construction of the muffler, however, takes a number of different forms. A number of forms are shown in Fig. 200. Baffle plates are used in the form at *A*, the gases being forced by them to expand from one chamber to the next so all the speed and pressure is dissipated before the outlet is reached. In the form shown at *B*, the gases are allowed immediate and sudden expansion from a comparatively small pipe into a large chamber. A series of annular chambers of large diameter but small depth forms the basis of *C;* the gas enters each of these chambers from the center through small holes, thence exhausting outwards, each chamber having an outlet around its circumference. In the form at *D*, the gases enter the central small pipe, escape through holes at its far end, which is blocked off, into the first concentric chamber where they travel to the front end where holes allow it to pass out into the second concentric chamber and out into the atmosphere. This is a widely used

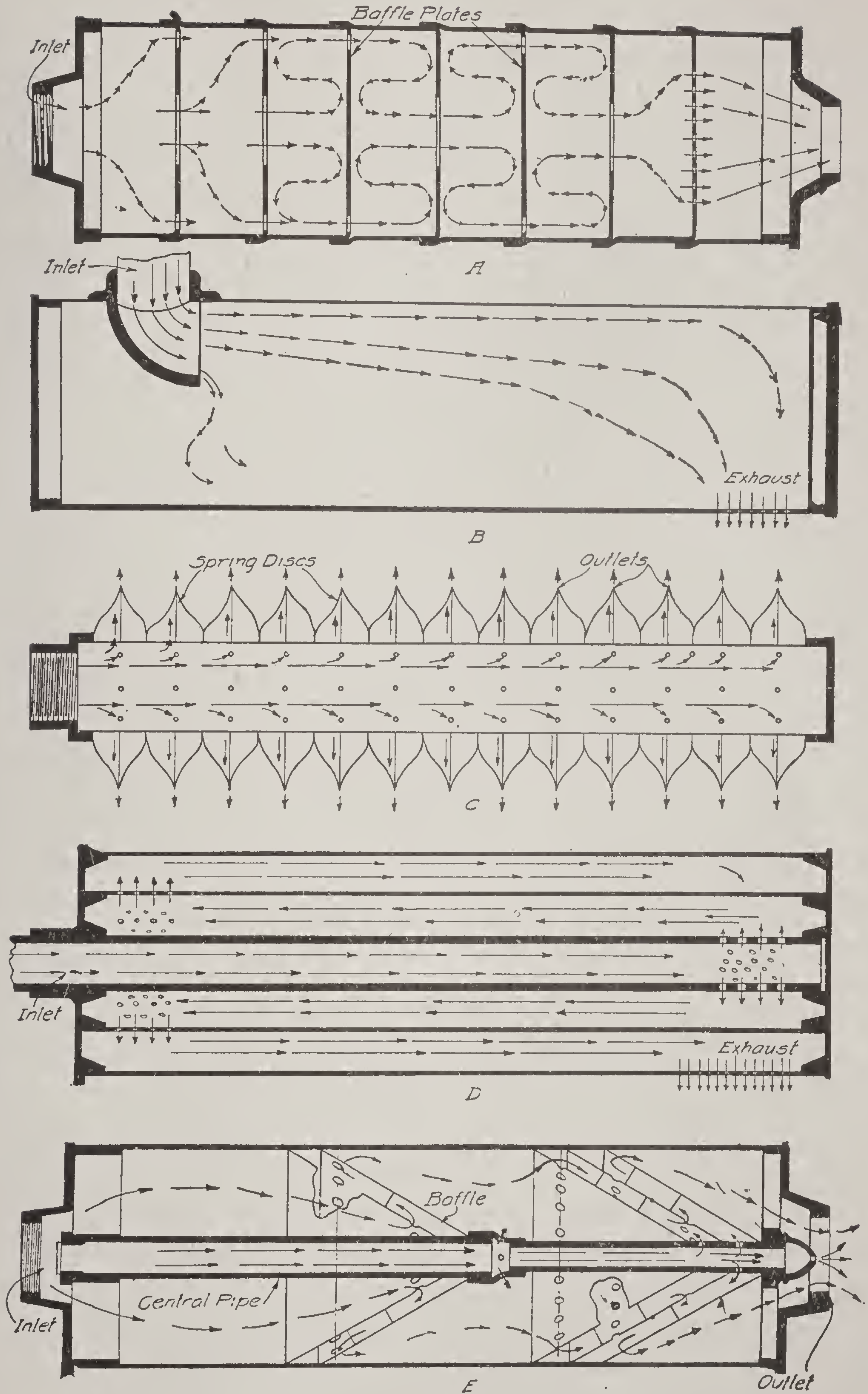


Fig. 200. Five of the Many Different Types of Mufflers
Courtesy of N. W. Henley Publishing Company, New York City

type. Cone-shaped baffles which force the gases to expand and then pass through very small apertures and expand again form the basis of *E*. This is the so-called ejector type, the passage of the gases from the large to the small end of the various cones being supposed to create a suction behind it which draws the gas out from the exhaust pipe continuously.

Muffler Troubles. When the engine mysteriously loses power, it is well to look at the muffler. A dirty muffler filled up with oil and carbon, which results from the use of too much oil in the motor, will choke up the passages so that considerable back pressure is created. When this is suspected, tap the muffler all over lightly with a wooden mallet, and the exhaust gases will blow the sooty accumulations out.

Cut-Outs. Formerly, the majority of cars were equipped with muffler cut-outs. By pressing the foot on the button operating the cut-out, the engine was allowed to exhaust directly into the atmosphere, cutting out the muffler. It served as a warning signal; it gave a good means of checking up the firing of the various cylinders; and several years ago, it was supposed to give greater power. Since its use was overdone, many cities and states prohibited such an arrangement on a car. Furthermore, the power loss has been proved a fallacy; consequently, the cut-out has gradually gone out of use.

On six-cylinder motors, and particularly motors with more than six cylinders, the sound of the exhaust is not an accurate guide to the firing of the cylinders, except for the expert mechanic with unusually keen hearing. The explosions of the six-, eight-, and twelve-cylinder engine overlap to such an extent that the weak explosion between two healthy ones cannot be detected. A missing cylinder can be found in this way, but not one that is simply getting a poor or weak spark.

COOLING SYSTEMS

WATER COOLING

Though nearly all successful automobile motors, as well as most other internal-combustion engines, are water-cooled, there is so much obvious fault to be found with this system of securing a result —involving first the generation of heat and then its waste by a complicated refrigerating system, instead of its utilization by converting more of the heat units into useful work—that it is scarcely credible that water cooling can persist indefinitely.

Water-Jacketing. The first essential in water-cooling a motor is to provide the cylinders with water jackets, through which the cooling water is circulated in contact with the outside of the walls within which the heat is liberated.

Water jackets are of two types, integral and built-up. The latter system of construction, though adding to complication and conducive to leakage, permits of lighter construction, besides diminishing the likelihood of hidden flaws in the cylinder castings, which, with cored jackets, are not likely to reveal themselves until they cause a breakdown, perhaps after the engine has been long in use.

Integral Jackets. With integral jackets, the usual system is to form the jackets by cores, in the founding, so that there are no openings in the jackets except those for removing the core sand and wires and for connecting the pipes of the circulating system. In many of the best examples of motor design, however, the core openings are left very large but with plane faces, and are closed by screwed-on or clamped-on plates, thus making the construction practically a compromise between the completely integral and the completely built-on jackets.

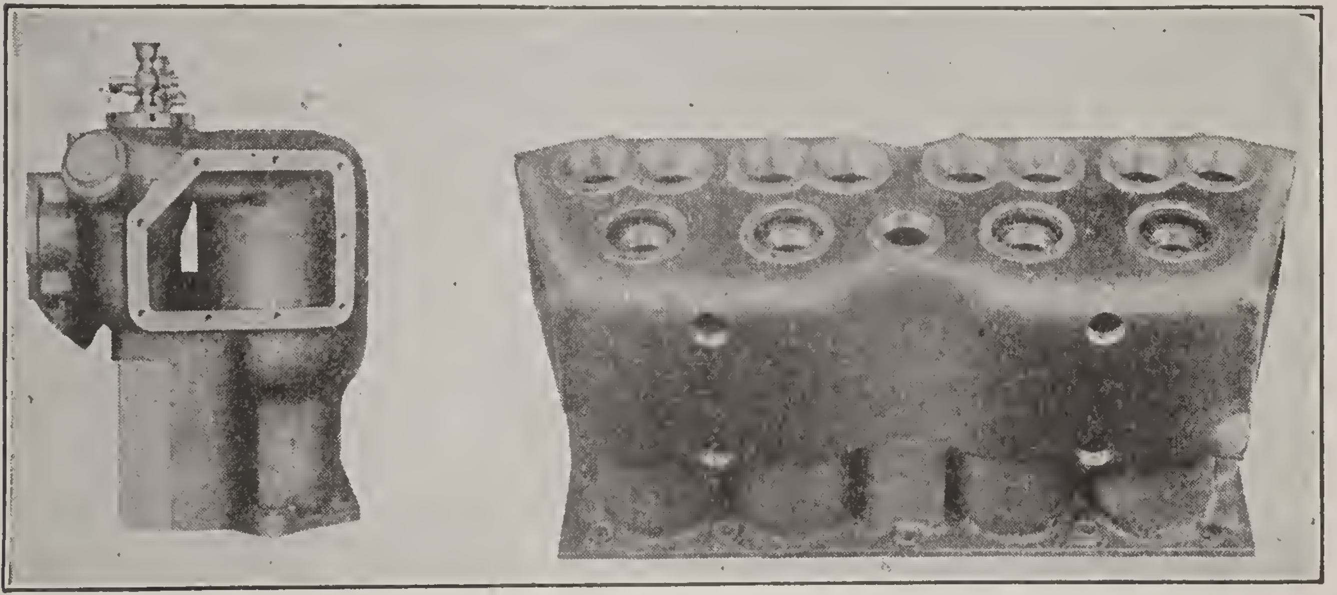


Fig. 201. Detailed View of Cadillac Cylinder Chassis

For example, in such modern construction as that shown in Fig. 2, a large plate will be noted on the ends of the cylinders. This covers a tremendous core hole, by the use of which the internal construction of the water jackets is made practically perfect in the foundry. This also allows easy inspection and cleaning, the removal of the two end plates enabling a person to see right through the water jacket from end to end. This latter-day construction overcomes all objections previously raised against troubles with complicated water-jacket cores. A detail of this cylinder block, showing clearly the arrangement of the end plates, the water passages around the cylinder bores, and other points, is presented in Fig. 201. The designers of large block castings for cylinders were forced to provide for easy inspection of this kind for self-protection, although in this connection, it is no more than fair to state that foundry men have made just as rapid advances in the art of casting automobile-engine cylinders and other complicated parts as the designers of machines have made in every other way.

Built-On Jackets. There are a number of forms of built-on water jackets, but few of these are in use at present. The best of these was the old Cadillac jacket, a cylindrical one-piece member with a junk ring, top and bottom, to hold tightly against water leakage. The form more often used is the applied plate, or sheet, which must be held by screws, flanges, or clamps. As these are not really successful in holding the water continuously, particularly against the combination of hot water, internal pressure, twisting, and racking action which comes from traveling over bad roads at high speeds, they are giving way to the older form of jacket.

An important advantage of applied jackets of the type just described is their freedom to yield in case the water freezes in them. The danger of cracked cylinders, which not infrequently results from exposure to cold weather in ordinary automobile motors having jackets integral with the cylinder, is eliminated.

A particularly neat method of water-jacketing, which has been applied with some success abroad, consists in the electro-deposition of copper jackets on the cylinders, through the use of wax molds, to produce the desired forms. Jackets thus applied, though somewhat expensive, are said to be practically indestructible and completely proof against leakage.

Welded Applied Jackets. The method of welding by the oxy-acetylene process promises to produce a cylinder with a cast-iron center and a sheet-metal water-jacket exterior made of pressed steel or of flat plates. The designers who consider this combination the best in that the thin sheet metal of copper or steel is lighter, radiates more heat, and will yield under freezing strains, will now be able to obtain such a combination at a reasonable cost. So far, however, it has been restricted to racing cars, in which the lightest possible weight is obtained regardless of cost. In a car to sell at an ordinary price, the cost might be prohibitive.

Radiators and Piping. It has often been pointed out that all cooling of automobile engines is, in reality, air cooling; the water-cooled motor is simply one in which the heat units to be disposed of are conveyed from the cylinders to the radiator by the circulating water, to be dissipated in the air that passes through it, instead of directly lost in air passing over thin flanges cast on the cylinders. A water-cooling system therefore constitutes a sort of indirect-air cooling. This being the case, the chief justification for water cooling consists in the margin it allows for much greater cooling areas in contact with air than it is possible to provide by mere extensions of the cylinder surfaces themselves.

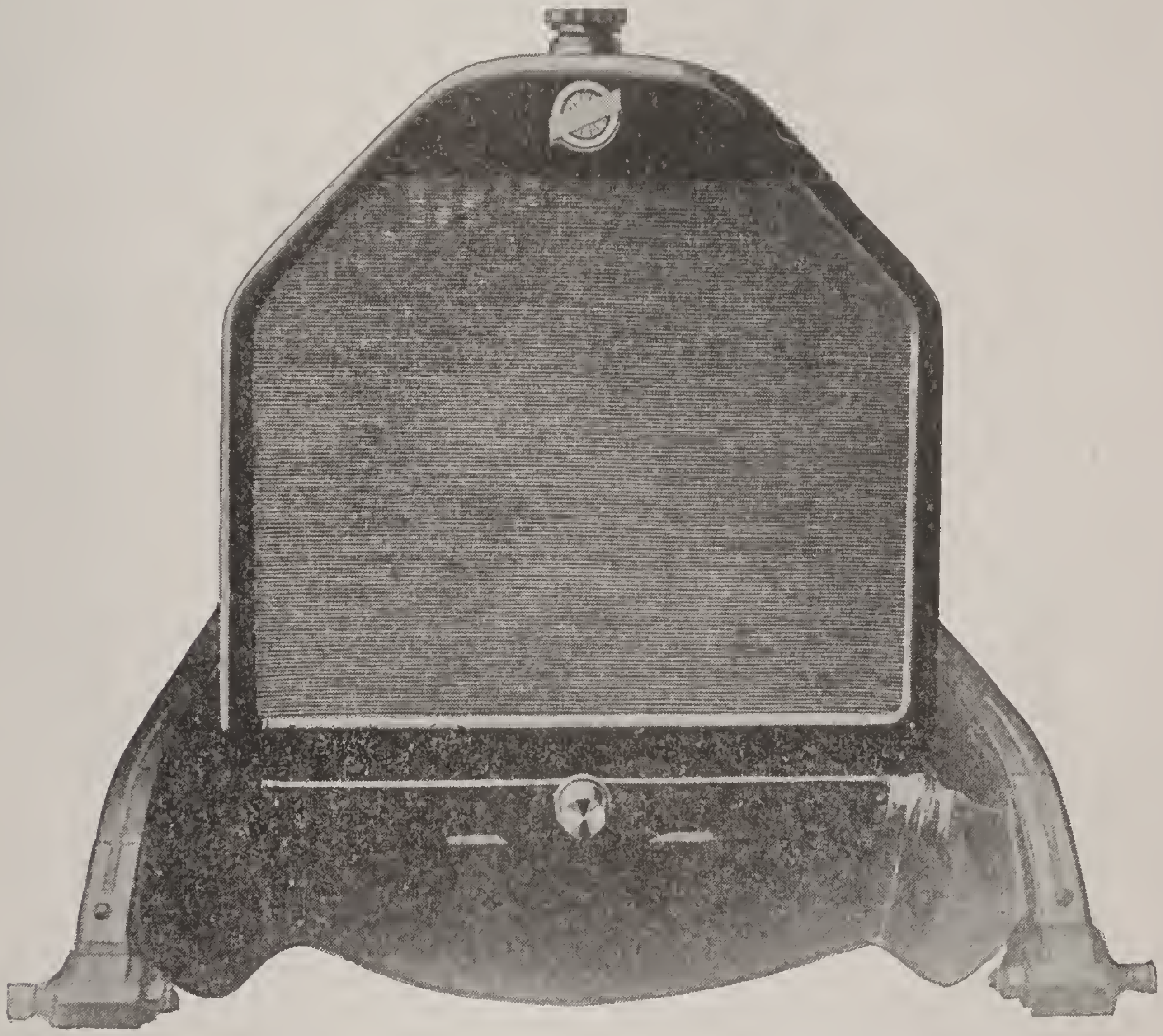


Fig. 202. Horizontal Plate Type of Tubular Radiator Used on Studebaker Cars
Courtesy of Studebaker Corporation, Detroit, Michigan

A typical pleasure-car radiator of the tubular type is shown in Fig. 202. As will be noted, the flanges have a continuous horizontal appearance, but the vertical tubes which carry the water can be seen in the background. These actually carry the water; the horizontal flanges simply serve as a heat-radiating surface. This type is rapidly increasing in popularity for pleasure cars of medium and low price, at the expense of all others.

The total cooling area of the radiators employed in automobiles will range all the way from ten to ninety square feet; the latter surface is not unusual in the best type of honeycomb radiators with hexagonal openings and very thin water spaces.

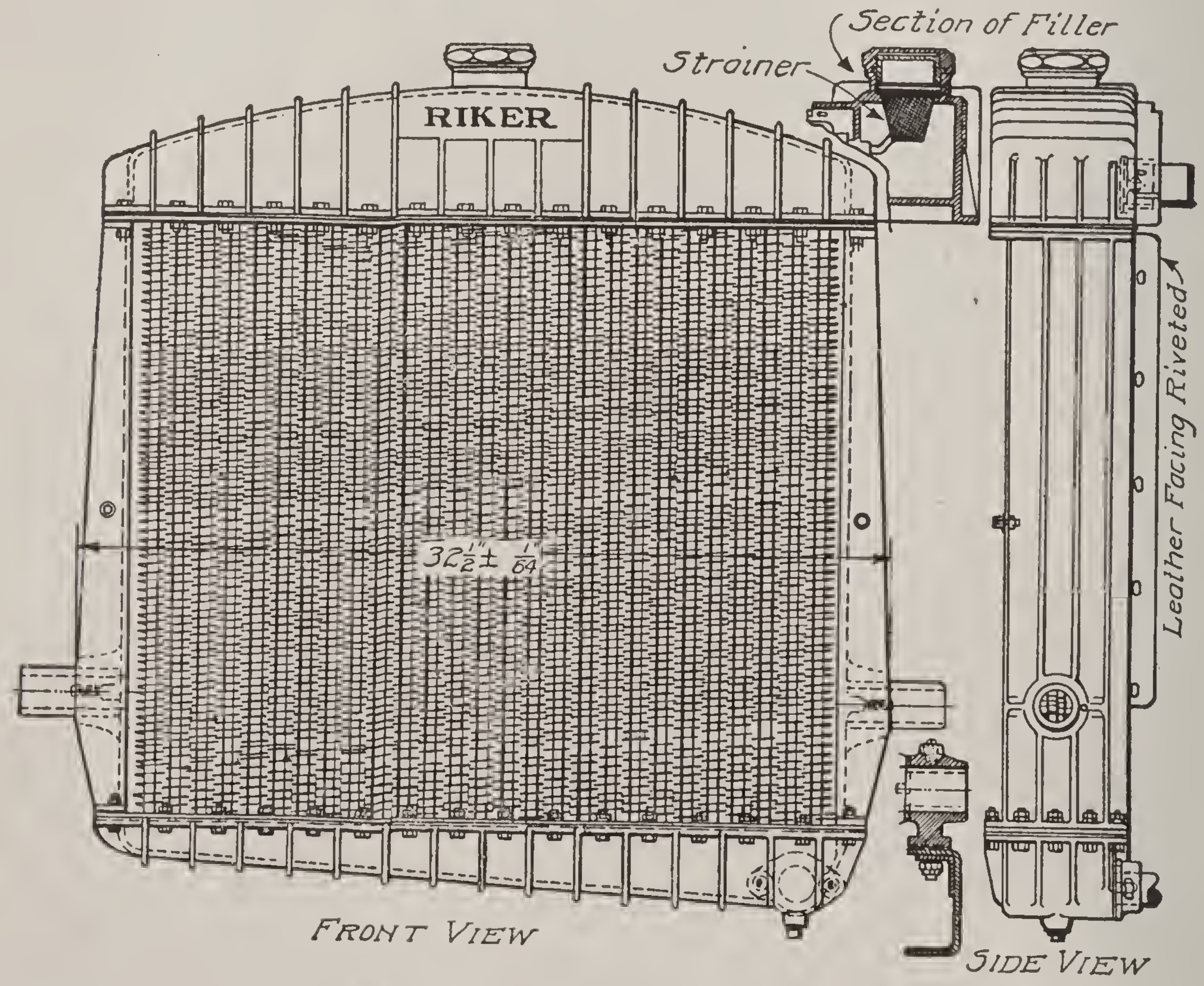


Fig. 203. Vertical Tubular Spiral Fin Type of Riker Truck Radiator with Cast Headers
Courtesy of Locomobile Company of America, Bridgeport, Connecticut

The smaller areas are found in the cheaper types of radiators built up of straight, round, or flat tubes, and provided with fins to increase the area exposed to the air. Radiators of these types, unless very large, are often inadequate to cool a motor when it is laboring under continued heavy usage, as in pulling on the low gear through deep sand or mud or up long heavy grades. Under such conditions, a motor that may have run for months without any cooling trouble whatever in level country will often boil all the water out of the cooling system within a few minutes.

Types of Cells. In the cellular, or honeycomb, radiator, there are three forms of tubing in general use. These forms are: the square, with its flat sides set horizontally and vertically; the round, with the tubes staggered so as to make the number as large as possible; and the hexagon, which is also set staggered so as to use the maximum number. The square and hexagon are more used on pleasure cars, while the round form has been used on higher-priced motor trucks. A modification of the round-tube form is found in the radiator which utilizes the plain copper tubes, bunched and fitted into a header, or water tank, at the end, but which are not formed into a composite unit. This is used on both pleasure cars and trucks.

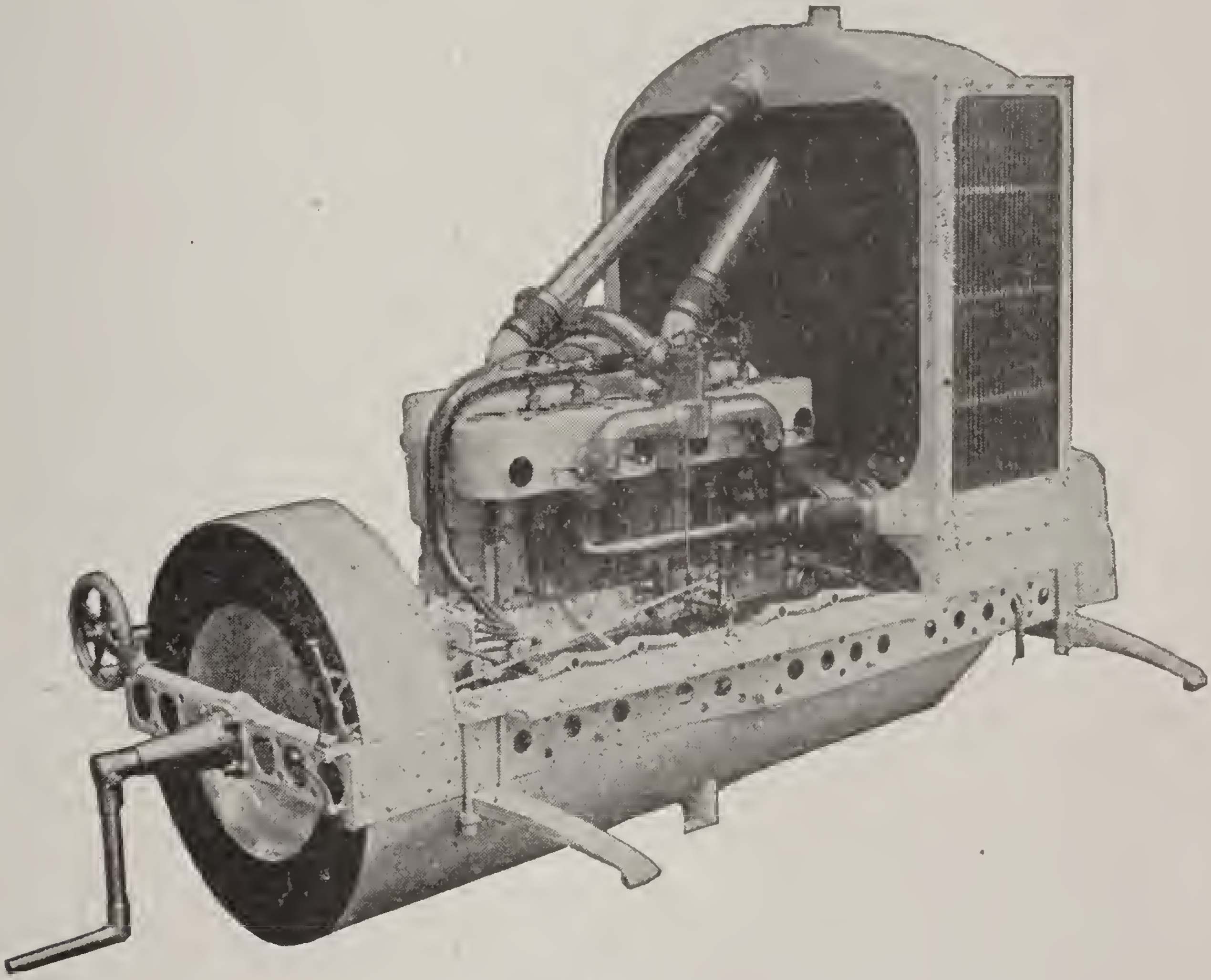


Fig. 204. Renault Form of Radiator Situated Back of Engine

Types of Tubes. In the tubular form, there are two well-known types: the round vertical tube with spiral fin, or flange, welded or sweated on; and the so-called tube-and-plate construction, shown in Fig. 202, in which a set of horizontal plates is pierced with a number of holes, tubes set into these, and the whole dip-soldered into a unit. The former type is gaining rapidly for truck use on account of its freedom from leakage under the severe racking conditions of truck use. An example of this type is to be found in Fig. 203, which shows a welded tubular radiator. It is of interest to note that the welded type replaced a soldered honeycomb unit of the highest quality which could not be kept water tight in war service.

Modifications of Cellular and Tubular Forms. In addition to the types shown in Figs. 202 and 203, there are a number of forms which

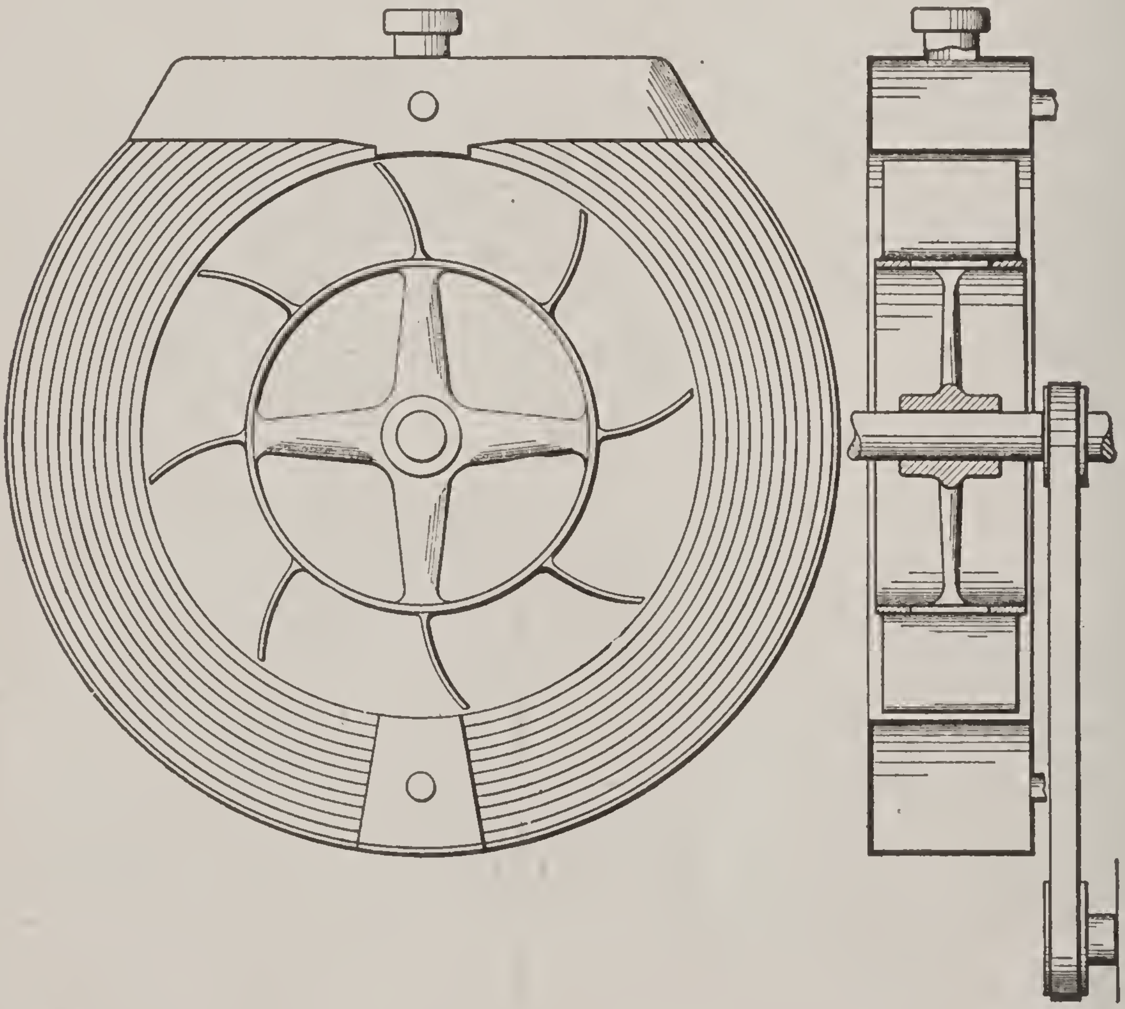


Fig. 205. Outline of Coiled Copper Tube Radiator Used on International Trucks

partake somewhat of their characteristics, but which show a marked individuality. The Renault form, which is placed at the dash instead of at the front, is shown in Fig. 204. It has a tank at the top and small tanks at the bottom and sides, the central bottom space being taken up by the fan. The tubes are of pure copper and are not fastened together as in the cellular radiator, but merely connected at the two ends. As compared with the average radiator of the cellular type of equal cooling capacity, this form requires greater height, width, and depth. Its dash position has the disadvantage of keeping the driver's compartment uncomfortably hot in the summer months.

Another modification along somewhat similar lines, which is used for a truck, is that shown in Fig. 205. This form consists of an upper tank, a small lower tank with the outlet, and a connecting group of copper tubes. It is made in the form of a circle of the largest possible diameter the tube structure will allow and of a width equal to the depth of the bank of tubes. The fan is placed in its immediate center. By placing the radiator at the rear end of the engine, the fan can be driven directly from the crankshaft or the flywheel, which gives the fan a higher speed. The unusual size and high speed of the fan circulates an unusual amount of air around the bare copper tubes. Copper is the best radiator of heat known except silver. On a truck, the position of the radiator at the back of the engine is held to be a big advantage, because the entire cooling system is protected from the frequent and unavoidable collisions of truck service.

The piping of automobile cooling systems in a great many cars is made too small to afford free circulation, and this mistake in design, common in the earlier days of automobile engineering, is one that cannot be too carefully avoided.

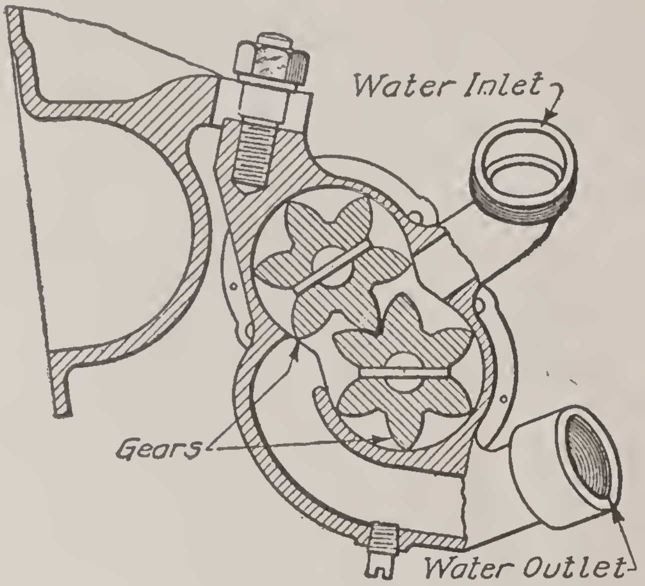


Fig. 206. Gear Type of Water Pump of Very Simple Construction

In the experience of most automobile designers, the most satisfactory method of connecting up the piping of a circulating system is found in the use of ordinary steam hose, clamped around the ends of the pipe by small metal straps.

The use of steam hose for practically the entire piping system is considered an improvement over the short hose connection by a few designers. It does away with metal piping altogether except as it extends from the radiator and water jackets for the attachment of the hose.

Circulation. An unobstructed and vigorous circulation of the water in a cooling system is a great factor in reducing the size of radiator required and in preventing overheating and boiling away of the water.

Pumps. The usual method of circulating the cooling water is to use one type or another of small pumps, driven by suitable gearing from the engine itself.

Gear pumps are often used for this purpose because of their extreme simplicity, but it is difficult to make them large enough to handle as great volumes of water as most designers now regard desirable.

A good example of the gear form of water pump is shown in Fig. 206. This is simply a pair of gears which mesh rather closely; the movement of the flat side of the teeth carries or forces the water forward. In general, the gears are made of small diameter but wide face to take advantage of this action. The result is a very compact pump. The vane type of pump is really a modification of the gear pump in that a rotating member is placed in an eccentric chamber with a sliding arm on either side, which is held out into contact with the sides of the chamber by a central spring. This double sliding arm simulates the effect of the teeth of the gear form. This has small capacity and is not widely used on that account.

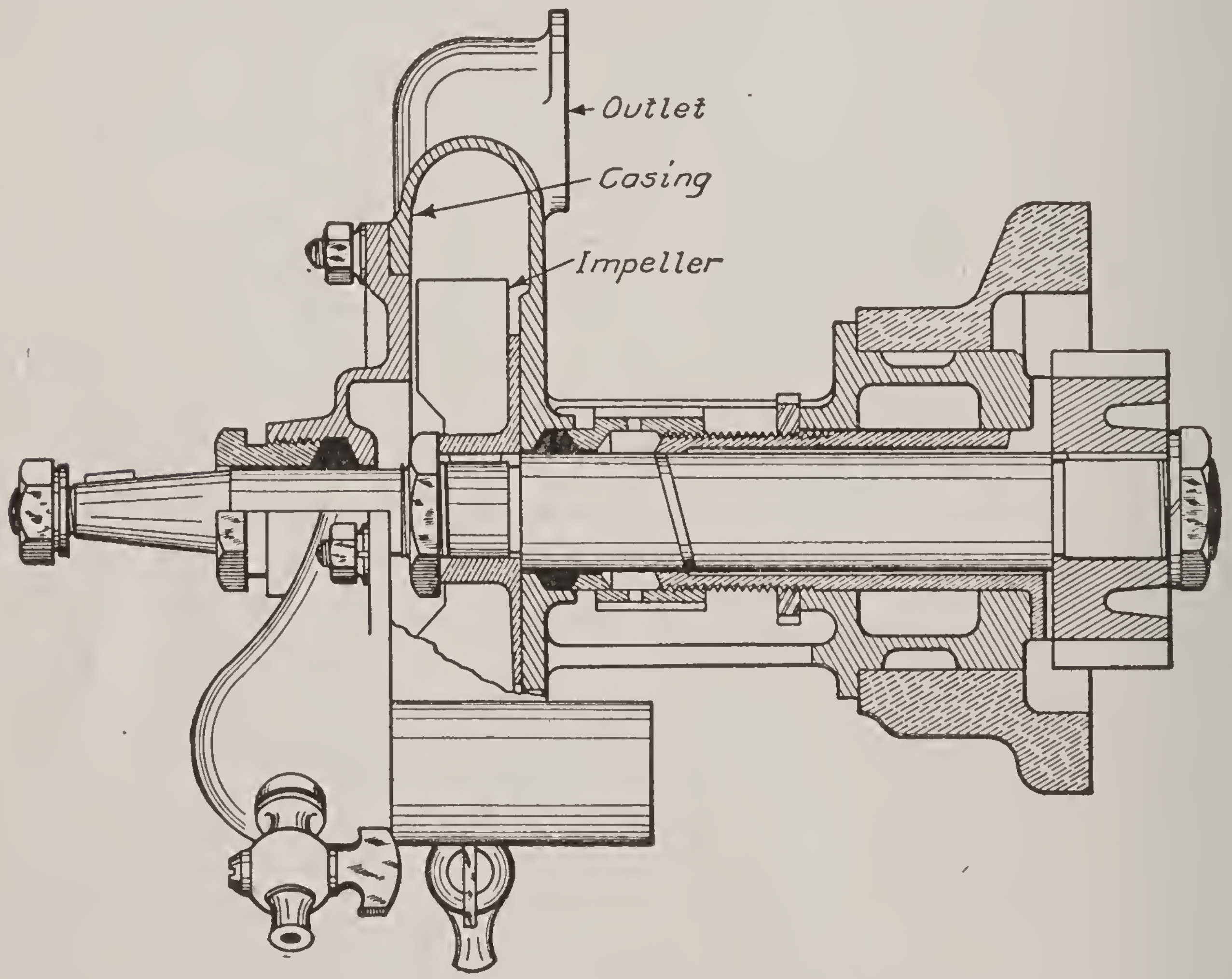


Fig. 207. Centrifugal Type of Water Pump as Used on Reo Cars

The consequence is that the centrifugal pump is now the type most preferred. In their best forms, centrifugal pumps consist of simple multi-bladed "impellers" revolving with close clearances in a housing.

One advantage of the centrifugal pump is that if any small object, such as a stick or pebble, should by any chance get into the circulating system—though strainers always should be provided to prevent this contingency—no serious harm is likely to result, whereas with a gear pump breakage is almost certain to ensue.

The construction of the centrifugal form can be seen in Fig. 207. This is not as clear as it might be because the impeller is sectioned at the point where the water chamber is largest; in short, at the water-outlet space. The impeller fits the casing very closely except at the water outlet where the water is thrown off by the centrifugal force generated in rotation. The centrifugal form of pump is also fairly well illustrated in Fig. 210, where it will be noted that two of them are used on the two ends of the upper shaft.

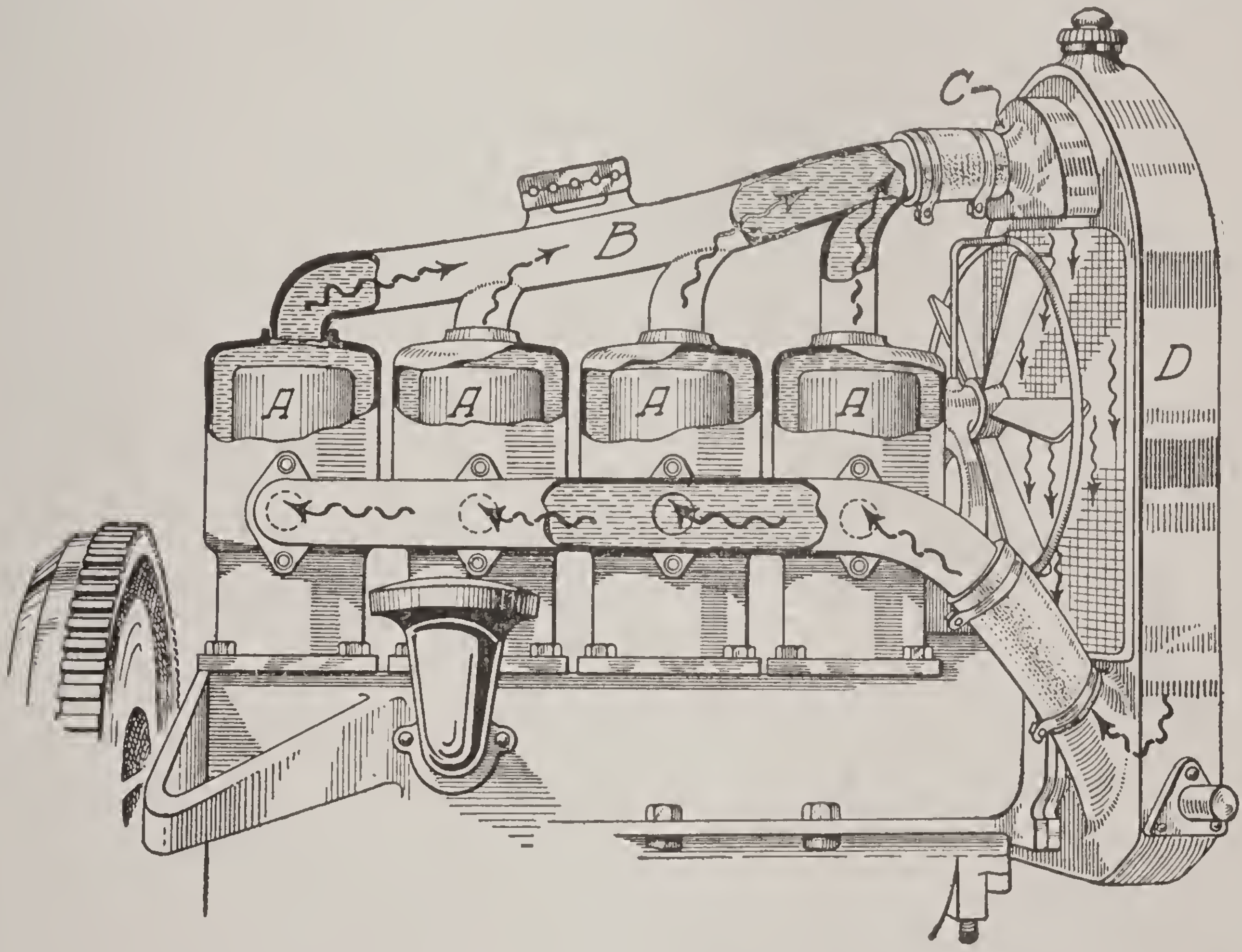


Fig. 208. Thermosiphon System of Cooling as Used on Overland Cars

Chiefly in motor-boat motors of the two-cycle types, reciprocating plunger pumps are used to circulate the cooling water. The volume of water handled by pumps of this type, of dimensions that can be conveniently employed, is not very large, however, and it is only the fact that the water is not re-used and is, therefore, cooler and of a consequently greater effectiveness that makes possible the use of plunger pumps in motor boats.

Thermosiphon. Circulation of the cooling water by the thermosiphon action, owing to the heated water in the jackets rising and the cooled water in the radiator descending, is the practice of an increasing number of designers, and has been demonstrated to be very effective with liberal jacket spaces and large-diameter piping.

The pioneer, and still the most prominent exponent, of thermosiphon cooling is the Renault Company, of France. A typical Renault motor-and-radiator combination with thermosiphon circulation is illustrated in Fig. 204.

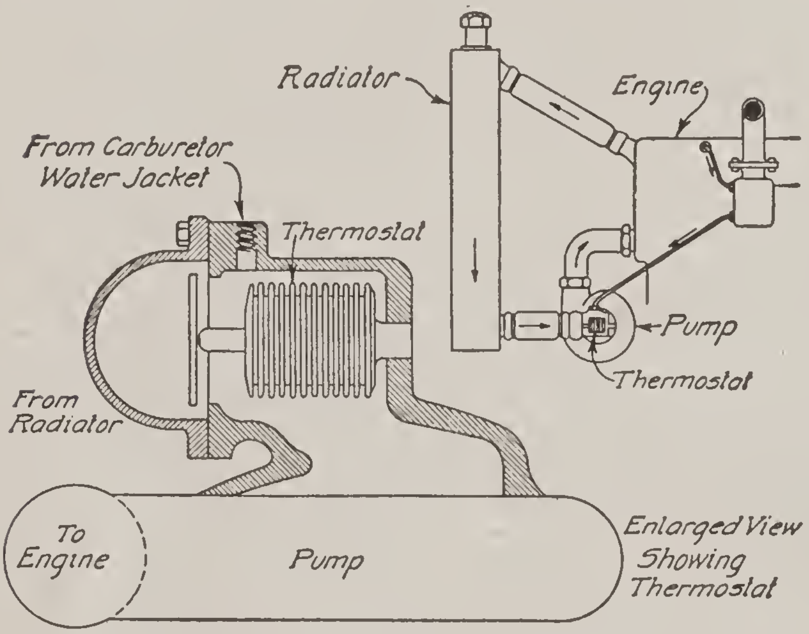


Fig. 209. Thermostatic Device in Latest Cadillac Water-Cooling System to Preserve Equilibrium and Even Temperature

A better example of the thermosiphon system, that is, a drawing which shows it much better is Fig. 208. In this the large open pipes with few bends, and those few very easy so as to reduce water friction to a minimum, are well shown, also the small difference in level between the top and bottom of the system. The difference in temperature causes the movement of the water. It is said that the pressure which the temperature variation produces is seldom more than a small fraction of a pound; for this reason it is necessary to reduce surface friction and losses at bends and at other similar points.

Cadillac System. An entirely new idea in the control of the temperature of the cooling water is that used on the new eight-cylinder Cadillac motors. Here, each block of four cylinders has its own circulating system, with pump and piping, entirely distinct from the other. In each one a thermostat, like that shown in Fig. 209, is located on top of the pump housing. This controls the movement of a valve, which, when shut off, prevents the flow of water to the radiator, that is, when the temperature of the water falls below a certain figure at which the thermostat is set, it comes into action and cuts off the flow of water from the radiator to the pump. The result is that the pump can circulate only that part which comes through the very small pipe to the inlet manifold and carburetor and from there back to the pump. This continues until the water becomes heated; the raising of the temperature operates the thermostat which opens the valve, and the system is again complete. In the upper right-hand part of this figure, the circulating system of one block of cylinders is shown in outline.

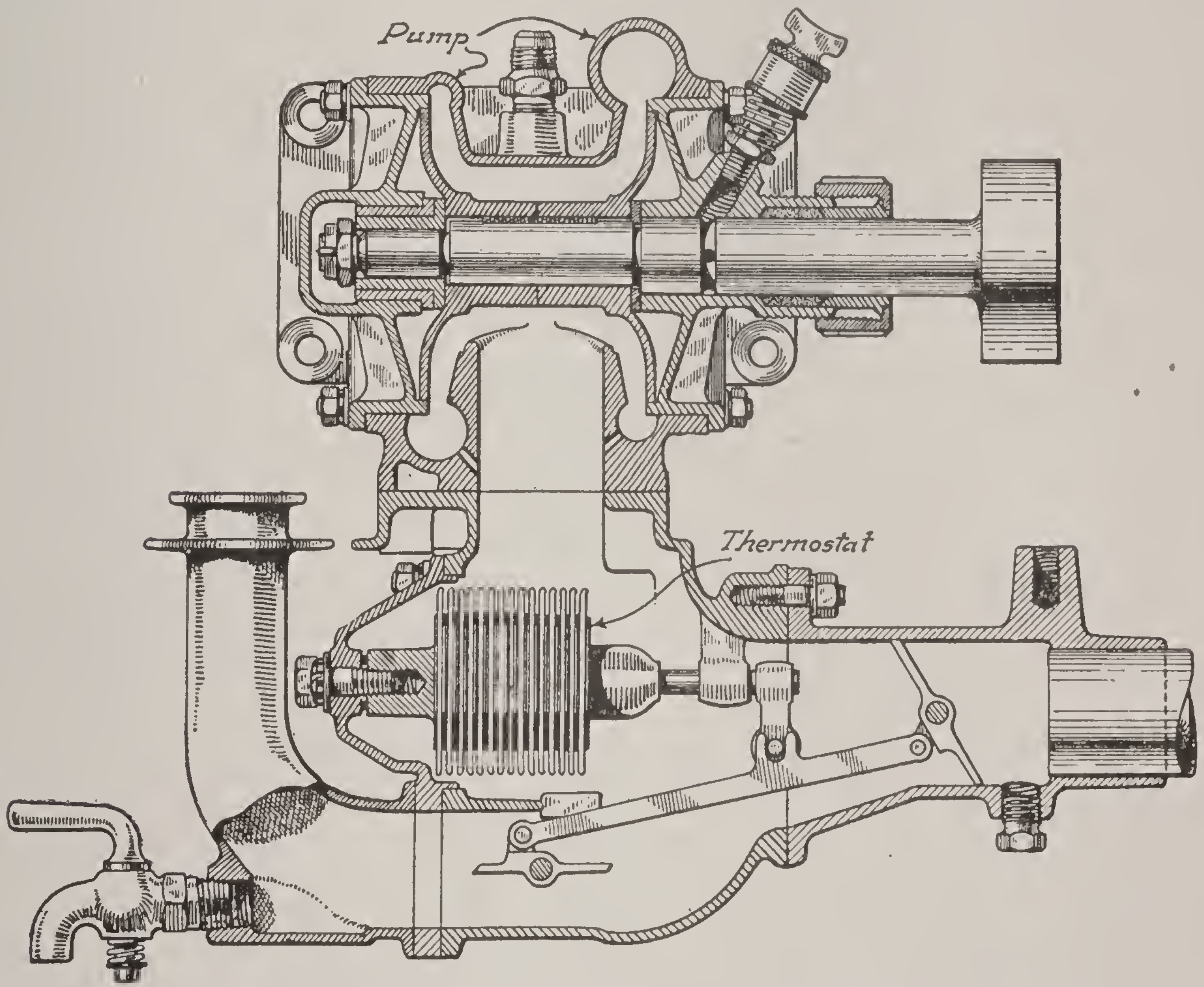


Fig. 210. Thermostat and Water-Pump Group on Packard Twelve-Cylinder Motor
Courtesy of Packard Motor Car Company, Detroit, Michigan

The method of controlling the temperature of the engine with an automatic check valve is receiving much attention; there is even talk of extending the same system of control to the exhaust gases and all sources of heat, interconnecting them with the fuel vaporizer so as to vaporize the maximum amount of fuel in the minimum time with the least heat loss. The thermostat and pump combination used on the Packard twelve-cylinder motor is shown in Fig. 210, in which it will be seen that two pumps are placed on the pump shaft, one at each end so that the thrust of each one balances the other. In the Cadillac, the two cylinder groups are separate, each having all the units shown in Fig. 209 except the radiator. In both the Cadillac and Packard systems, the thermostat is placed at the bottom of the system. It has been advocated by engineers for other companies that this would do the most good if placed at the top of the system.

The value of a thermostat may be gained from these figures. One particular make of thermostat, as used on a popular make of car, was tested out with the following results: Without it, the car did 14½ miles on a gallon of fuel at 15 m.p.h. and 13½ miles at 30 m.p.h. At the same speeds and with the thermostat set at 160 degrees, the same car under the same circumstances did 16½ miles at almost 15 m.p.h. With everything the same but with the device set to work at 180 degrees, the car did 19¼ and 16¼ miles, respectively. The gain at the lowest speed of 15 miles an hour from 14½ to 16½ and then to 19¼ miles per gallon represents gains of almost 14 and 38 per cent in economy.

Fans. In the earlier days of automobile designing it was deemed sufficient to secure circulation of air through the radiators by the movement of the car alone. This was soon found inadequate, however, for often when most cooling was needed, as in hill climbing or hard pulling on the level, the car would be moving at its lowest speed on low gear, with the result that the air draft through the radiator was not sufficient to cool the water.

This condition was remedied by the use of a fan behind the radiator, driven by a belt or gearing from the motor so as to draw a constant draft through the radiator in proportion to the speed of the engine rather than of the car.

Nowadays, practically all automobile power plants are provided with fans, the only exceptions being a few very small motors in which the difficulty of cooling is not so great as with the higher powers.

In some cases, instead of a separate fan,. fan blades are placed on the flywheel, and so made to induce a draft through the bonnet that covers the engine, thus avoiding the necessity for the addition to the moving parts involved in the usual fan system. Such a flywheel fan is used in the engine illustrated in Fig. 204.

A later plan of even greater effectiveness is the housing-in of the whole rear end of the radiator, so that what air passes through must pass through the center where the fan is located. This is but another way of saying that all air must pass through at a high velocity, which insures efficiency. This plan fulfills one requirement of air cooling, that is, the large quantity of air which must be used.

Where this system is used now, the entire engine in front of the fan is made air tight. The hood, which has no openings anywhere, is set into carefully fitted rubber strips to cut off any possible leakage. The same precautions of drawing all the air through the radiator, and through that alone, are observed elsewhere. While this method is effective, it is a disadvantage in another way, for some direct cooling is effected through the cylinder walls, exhaust pipes, etc., in the ordinary system by the cold air passing over the radiator, particularly the air which comes in from around the hood top and sides.

Anti-Freezing Solutions. In using automobiles in very cold climates during the winter months, there is great danger of the water in the cooling system freezing when the car is standing still, or even with the motor running slowly if the temperature is very low. The result of such freezing is almost certain injury to the cylinders, through cracking of the water jackets, as well as the probability of bursting out radiator seams, with consequent leakage.

To avoid these difficulties it is not uncommon to use, instead of pure water, one kind or another of anti-freezing solution, usually compounded by the mixture of some chemical with water to lower its freezing point. Thus, glycerine or alcohol mixed with water will keep it from freezing at all ordinary winter temperatures. Glycerine is somewhat objected to because of its sticky, gummy nature, and also because of its deleterious effects upon the rubber hose of the piping system. Alcohol, if not replenished from time to time, will evaporate out of the water and thus permit it to freeze, or, if mixed in too great a quantity, it may introduce a fire risk otherwise avoidable.

A much favored anti-freezing solution consists of calcium chloride dissolved in water, in a quantity proportioned to the temperatures that it is desired to guard against.

All anti-freezing solutions are more or less objectionable in that they are more likely than pure water to corrode and clog up the circulating system, and there is no doubt that the elimination of the necessity for them by the substitution of air cooling for water cooling will mark a great advance in automobile development.

AIR COOLING

Though successfully employed in one or two automobiles and remarkably developed in some of its applications to aviation motors, air cooling is not considered by most engineers to be successfully applicable to the average automobile. That it will become more practical in the future, however, is the opinion of many.

Unfortunately, this is an instance where the better and simpler method does not meet with popular approval, that is, the cooling of automobile cylinders is one of those cases in which the best in theory is not, by any means, accepted practice. The extent to which the public has adopted water cooling as compared with air cooling may be noted in these figures for 1916: Cooled by air, 1 car; cooled by water, 168; total, 169.

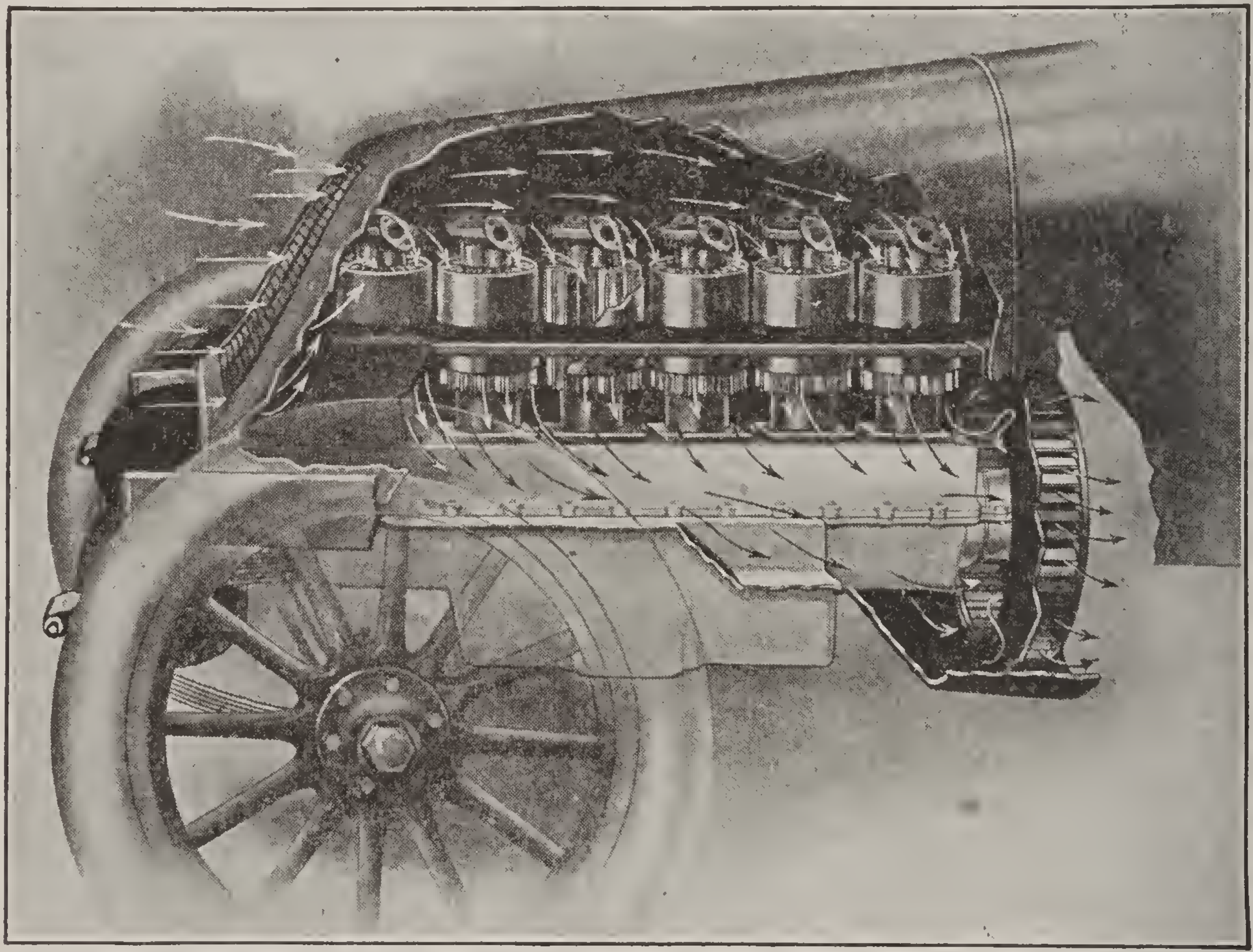


Fig. 211. Diagrammatic Illustration Showing System of Air Cooling on Franklin Cars
Courtesy of H. H. Franklin Manufacturing Company, Syracuse, New York

Flanges, or Fins. The usual method of air cooling, successfully employed in aviation and motorcycle motors and in a few automobiles, is to provide the cylinders with fins, or flanges, for increasing the area of the surface, supplementing this with means for blowing large volumes of air over the surfaces thus provided.

Air Jackets. Several of the most practical examples of air-cooled motors in aviation construction are those which have, in addition to the flanges, or fins, on the cylinders, air jackets to concentrate the drafts of air that effect the cooling.

Blowers and Fans. The most successful air cooling has been accomplished by types of blowers capable of inducing much more vigorous air currents than are drawn through the radiators of water-cooled automobiles by the types of fans commonly used in power plants of that character.

In the Franklin, the most successful air-cooled automobile motor, a side view of which can be seen in Fig. 211, the cooling is a sort of combination of the flange and the blower method. The fins are vertical and radial, with a close-fitting hood connected to an air-tight pan. At the only opening in this hood, which is at the rear end, is placed the fan (on the flywheel). This draws the air past the cylinder walls, where it is needed.

Internal Cooling and Scavenging. Perhaps more promising as a road to final and universal use of air cooling are the systems of pumping air through the interiors, instead of blowing it over the exteriors, of the cylinders. Such internal cooling, in addition to directing the maximum cooling effect where it is most needed on the oil-coated surfaces that are exposed to the heat of combustion, has the further advantage that it may be made to scavenge out all residual exhaust gases, which, besides helping to accumulate heat, also act so detrimentally upon the functioning of ordinary motors. This is a direct result of the admixture of retained exhaust gases with incoming fresh charges.

Methods of internal cooling and scavenging that appear of definite promise are those proposed in various recent schemes for pumping air first into the crankcase—either by using the under side of the piston as a pump, as in common two-cycle constructions, or by applying special pumps to the crankcase for this particular purpose—then into the cylinders by means of by-passes, with the result that it exerts a positive cooling effect inside the cylinder.

In England, some interesting experiments have been made on a theory of internal cooling in which water is introduced into the cylinders in the form of a spray, at certain points in the cycle. This is said to add power in addition to helping the cooling.

COOLING TROUBLES AND ADJUSTMENTS

Cleaning. It is highly important that the cooling system be entirely cleaned out at least once, and preferably twice, a year. When this is done, the water jackets and radiator should be flushed out with a strong current of water, preferably a hot soda solution. This should be forced through in a direction opposite to the usual course of the water. Thus, a hose can be put in the radiator filler cap and city pressure applied to force the water through; in this radiator, it will be made to go from bottom to top instead of the usual top to bottom. If this method, which is the usual and easy one, does not remove all dirt, sediment, and foreign matter, the radiator can be removed and boiled, or at least submerged, in a strong soda solution which will clean it out thoroughly. The radiator is the most important member of the system.

Replacements. When this is done, it is advisable also to look over all hose and hose connections. Many times the hose will have become worn or frayed through and cut or otherwise damaged from the outside, or the water may have attacked it from the inside, particularly if it has been through a winter when an anti-freezing solution was used. It is well, when cleaning the system, to replace all hose with new. The clamps are important as they determine the water tightness of the hose, so they should be looked over for missing nuts, broken screws, broken clamp ends, as well as to note if each one is applied straight and true over the hose and the end of the pipe on which it is placed.

Washing. If the radiator is splashed with mud or dirt, the washing should be done from the rear, with the hood removed. This method allows free use of the hose, and at the same time it insures against getting any water in the ignition system where it would cause trouble.

Adjusting=Fans. Usually, the fan is hung on an eccentric bushing held in a clamp. It is important that the fan belt be tight enough so that there is no slippage, otherwise the engine will heat up. To tighten a belt, loosen the clamping bolt on the fan eccentric, and then turn this eccentric so as to move the fan-shaft center away from the crankshaft-pulley center. The eccentric may be moved with the hands, in some cases; in others, a wrench is provided, and the fan eccentric made with surfaces on which the wrench fits; while still others need the application of a pointed tool and hammer to turn it. In the latter case, do this very carefully so as not to chip off any metal. Occasionally, the fan bearings need adjustment or lubrication. When they are of the plain type, a grease cup is generally provided, and after the engine is stopped, a couple of turns of this will be sufficient. If of the ball or roller type, they will be packed in grease, and if they show signs of running dry, the fan should be taken apart and the grease renewed. Use a good grade of cup grease for this purpose, not a hard grease.

Adjusting Pumps. Generally, the pump is made so as to need no adjustment. However, a leak may occur at one of the packing nuts. To remedy it, tighten the nut as far as possible, but if this does no good, remove the nut and add packing under it. Special packing is provided for this purpose, but if no other is available, a thick heavy piece of string can be well coated with graphite or a graphite grease and wound on as packing. In putting on packing of this kind, it should be wound on right handed, or in the same direction as the packing nut turns to tighten. Otherwise, tightening the nut will loosen the packing.

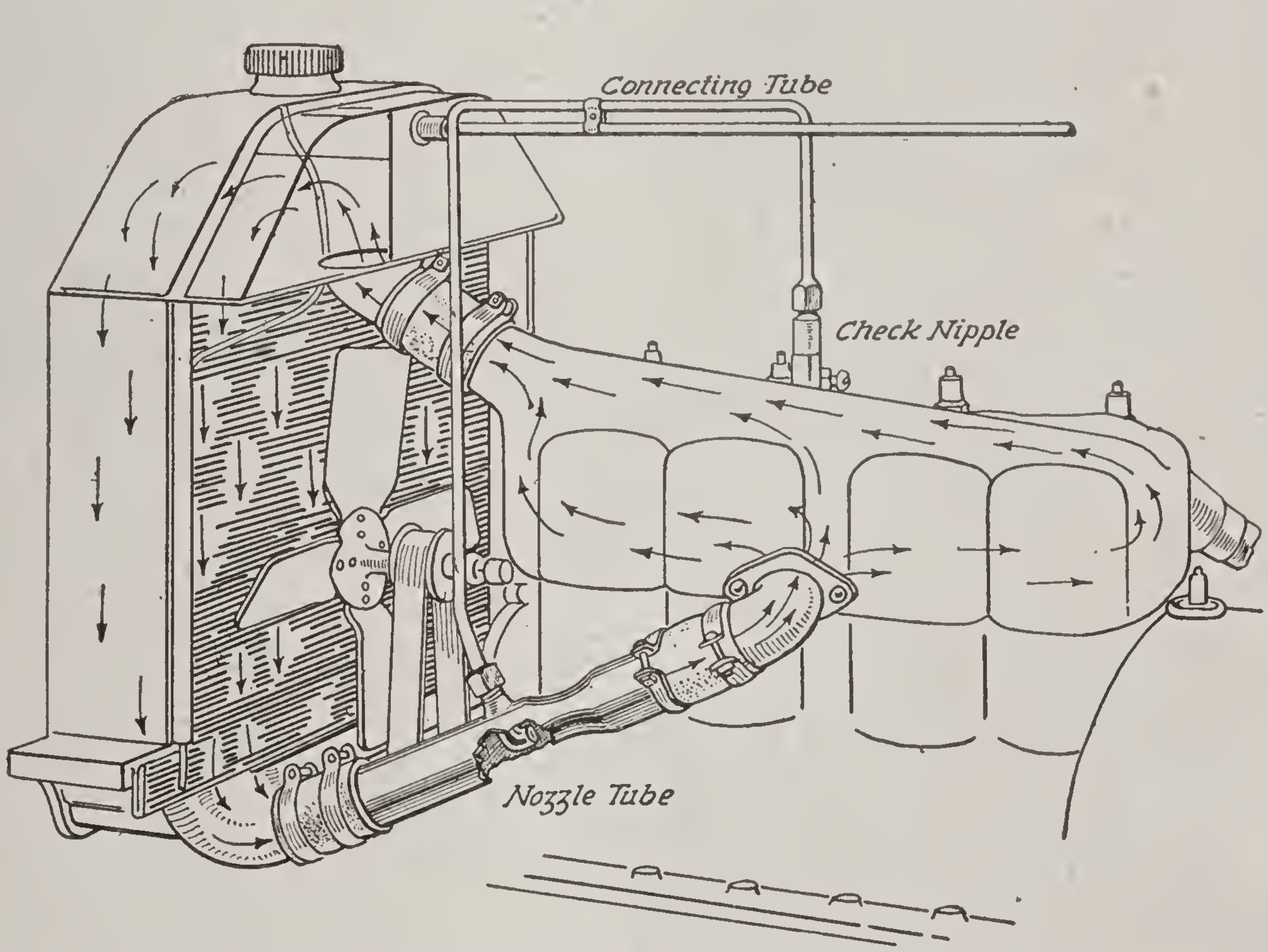


Fig. 212. Perfection Device Utilizing Exhaust-Gas Pressure to Improve Ford Water Circulation

The Ford motor circulation is of the thermosiphon order, but often, for one reason or another, it does not do well, so the motor continues to heat, although everything appears in good condition, fan belt tight, etc. For such cases, an additional means of circulating the water is needed. There are several devices on the market, one consisting of a form of screw set into the water pipe with the idea of stabilizing the flow of water. Another, Fig. 212, uses the force of the exhaust gas by-passed through a small special pipe into a nozzle of the ejector type placed in the water inlet to cylinders to make the water flow more rapidly and evenly. It is said that this uses but 3 per cent of the exhaust gas and that it is designed to keep the water system working at 195 degrees, which is a very efficient point, more power being developed at temperatures approaching the boiling point than at low temperature. In addition to improving the water-circulating system, this device is said to eliminate carbon formation and save 20 per cent of the fuel and oil.

In general, the cooling system is an easy one to take care of and repair because such a large part of its units and components are foolproof. Moreover, it is a system which gives visual and other evidences of derangement.

Summary of Cooling Troubles

Anti-Freezing Solutions. The following are satisfactory formulas for anti-freezing mixtures:

1. Mix equal parts of glycerine and water. Replace evaporation with clean water. Replace leakage with fresh solution.

2. Mix equal parts of denatured alcohol and water. Replace evaporation with alcohol and replace leakage with solution.

Radiators. Radiators must be kept well filled. Leaky radiators are difficult to repair. This work should be done by an experienced radiator man, never by a plumber.

Soft Water. Soft water should be used for filling tank. It should be borne in mind that the circulating water gets pretty hot, and that incrustation may result from hard water.

Engine Heats, Loses Power, and Knocks. These are all symptoms of lack of water circulation. To see if this is the case, look into the opening in the top of the radiator and see whether water is flowing in from the engine. If not, either the water-piping system is stopped up, which can be checked by disconnecting, or else the circulating pump is not working properly. All modern engines are so proportioned that, in this event, the water continues to circulate by thermosiphon action. Taking off the pump will verify this.

LUBRICATION SYSTEM

MOTOR LUBRICATION

When the lubrication system is referred to, that of the motor is generally meant. Motor lubrication is of the highest importance; for the motor must have efficient and continuous lubrication to run properly. Taken in its broadest sense, however, the title should refer to the entire lubricating means of the car; that is the way it will be handled here. The other units and parts of the car may not need as efficient or as continuous means of lubrication as the engine, and the presence or lack of lubricant is not so tremendously important; but all of it is of value and influence in the operation of the car, and should be well known.

Interior and Exterior Demands. The engine of a motor car requires two distinct kinds of lubrication. The interior parts, which are subjected to the greatest heat, rotate or slide at the highest rate of speed, and generally do the greatest amount of work, must have what amounts to a continuous stream of good lubricant. With the exterior parts, which do not rotate so fast, do less work, are not subjected to much heating, and will be kept cool by the atmosphere, there is no need for this continuous stream, nor for such a quantity or high quality of lubricant.

The exterior and interior systems must be considered separately. With reference to the internal oiling, there are two general systems in use: the pressure form, and the splash type. A third, which is now coming rapidly into use, is a combination of the two, called the splash-pressure system. For 1917, the relative popularity of these three is as follows: pressure, on 30 per cent; splash, on 35; splash-pressure, on 35.

In the pressure form (or its modification, the splash-pressure), the pressure may be produced in a number of ways: by a single large pump; by a series of small pumps, one for each bearing lead; or by a reservoir, or tank, kept filled by a separate pump (gravity pressure).

Splash-Pressure Feeding. One of the best and most successful types of lubrication systems is that in which the oil is fed under pressure to the different bearings.

In the splash-pressure system, the oil to all the crankshaft and connecting-rod bearings, to the timing gears, and to the upper portion of the cylinder walls is supplied through the medium of a gear-oil pump driven usually by worm gearing from the camshaft. The other bearings within the engine are lubricated by oil spray thrown from the crankshaft. Such a system is shown in Fig. 213.

Overland. The same units are necessary in all splash-pressure systems, but they can be and are used in widely different ways. It is of interest to the repair man to know the details of a number of these methods so as to be able to repair and adjust the mechanisms more readily, also to more quickly point out their troubles. One of the most simple systems in use is that of the Overland, as shown in Fig. 214. In this, the oil pump at the bottom of the oil sump *A* is driven from the camshaft rear end. After passing through the strainer *B*, the oil continues through an outside pipe to the sight feed *C* on the dash. This simply indicates that the system is working continuously.

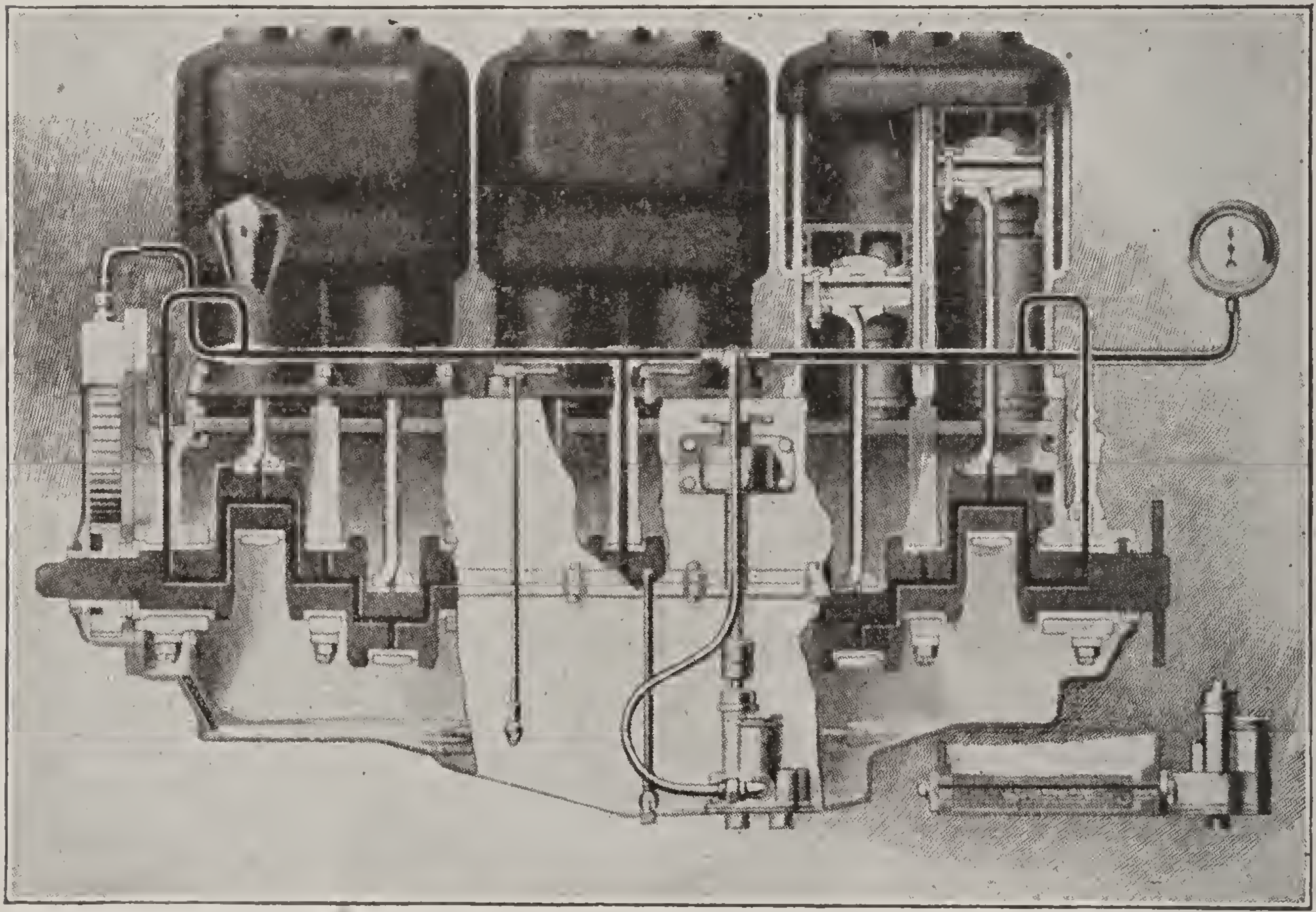


Fig. 213. Pressure-Feed Lubrication System on Pierce-Arrow Cars
Courtesy of Pierce-Arrow Motor Car Company, Buffalo, New York

From here it passes back through the pipe *D* to the inner distributing pipe *E;* this serves to keep the troughs *FF*, filled. At the middle part of the downward stroke, the scoop on the bottom of each connecting rod dips into its own oil reservoir and splashes up a fine spray of oil. At high speeds, the four rods fill the whole interior of the crankcase and the lower parts of the four cylinders with a mist of oil. This is sufficient to lubricate everything thoroughly. In a system of this kind, the strainer is of great importance and must be kept clean. Similarly, the oil sump should be drained very frequently, at least every 1000 miles.

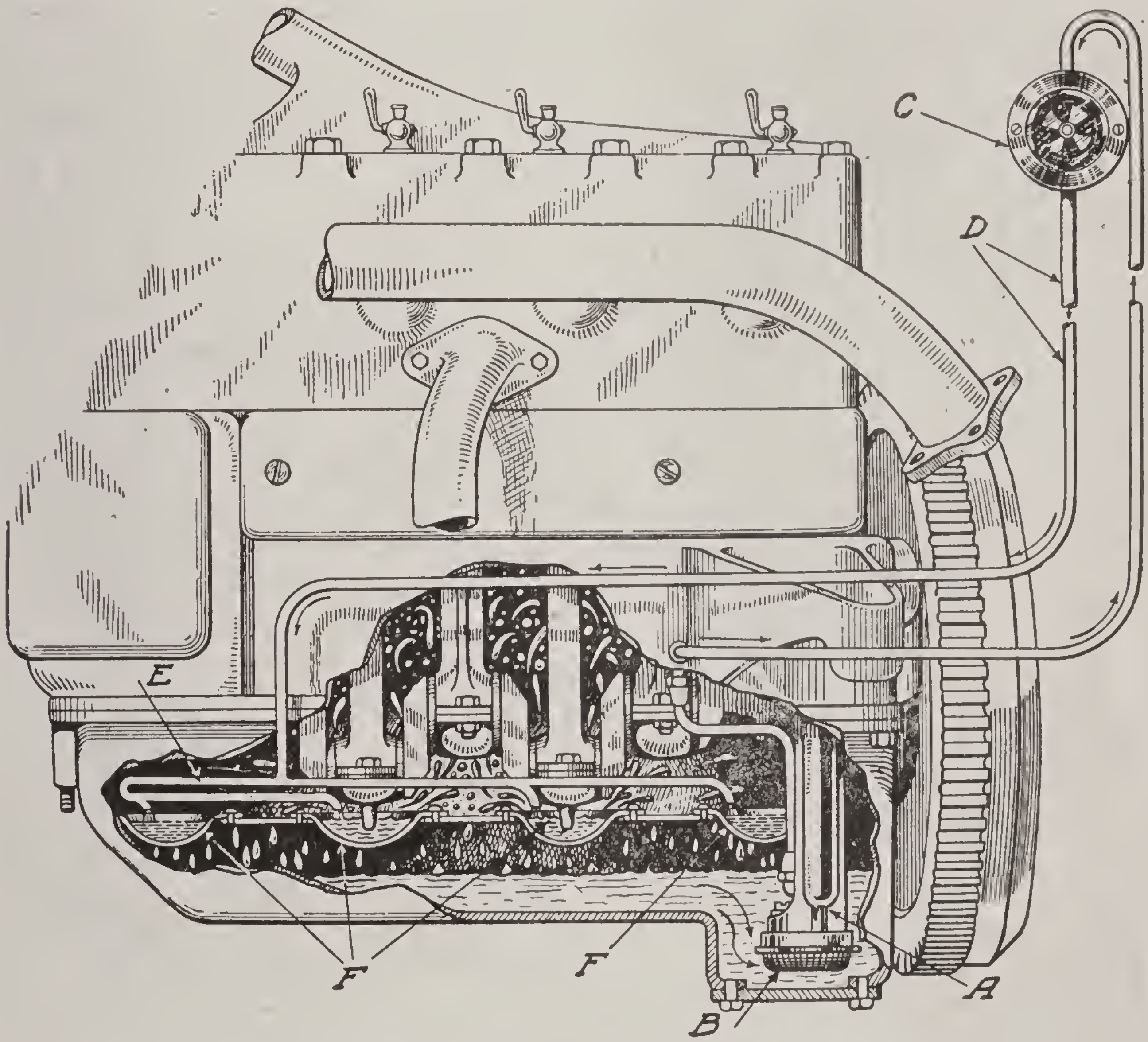


Fig. 214. Constant Level Splash System on Overland, in which Pump Maintains Oil Supply at Predetermined Level

Studebaker. The Studebaker system is very similar, except that the oil pump is outside of the crankcase and set higher up. It is of the simple gear type and is not liable to derangement. The system is equipped with an oil-level indicator on the side of the case, which shows the quantity within the case.

Single=Pump Pressure Feeding. The drilled crankshaft, as shown in Fig. 213, is a necessity in all pressure systems, as it also is in all combination splash-pressure systems. This can be seen, and perhaps the whole system explained more clearly, by referring to Fig. 215. In this the single pump working direct is used, thus differing from the reservoir system explained above. This diagram shows also how the oil is forced to flow through the three bearing leads to the interior of the crankshaft, whence it follows in to the pins upon which the connecting rods work. These rods are drilled, and the oil is thrown out by centrifugal force, passing up through the rods to the piston, thence onto the cylinder walls. In addition, the latter are sure to receive sufficient lubricant, for the rotating shaft and rods throw off a good deal in the form of a mist which settles upon the cylinder walls.

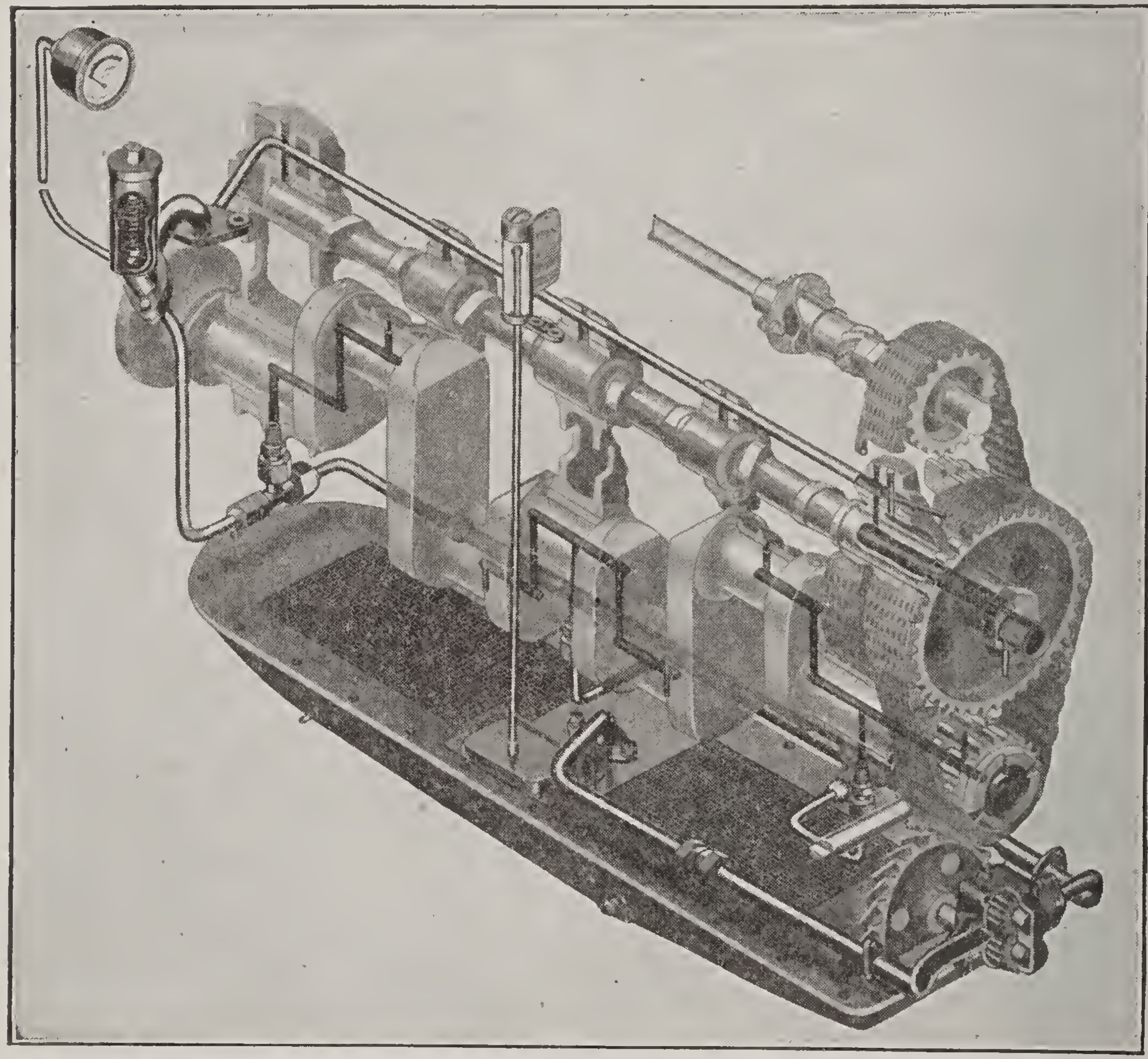


Fig. 215. Lubrication System of Cadillac Eight, Showing Pump and Path of Oil, Also Auxilliary Circuit for Crankshaft

Generally, pockets are provided inside the motor to catch the mist and force it to flow to the camshaft and other bearings besides the crankshaft, but in this case it will be noted that the camshaft bearings have individual supplies through the medium of a camshaft oiling pipe.

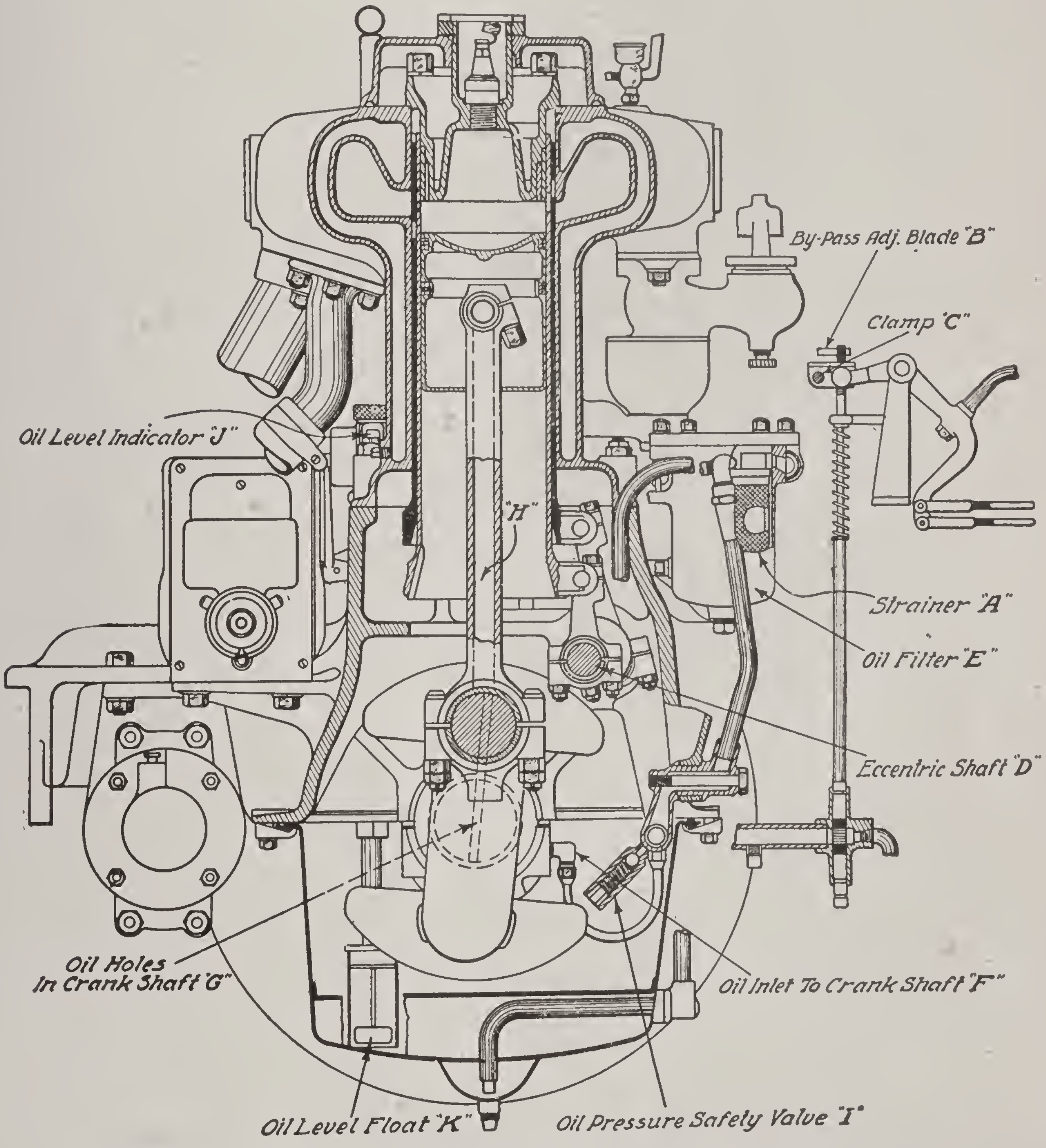


Fig. 216. Pressure Lubrication System Used on Stearns-Knight Motors
Courtesy of F. B. Stearns Company, Cleveland, Ohio

An objection to lubricating systems of this type is that in case there are several leads to different bearings one of them may become obstructed without anything to indicate this condition or to overcome it until the bearing involved becomes overheated and ruined. If one lead becomes obstructed, the oil can still continue to feed out through the others, thus relieving the pressure in apparently the normal manner and failing to reveal a serious derangement.

Stearns. The Stearns-Knight system is shown in Fig. 216. The oil is circulated by a pump (not visible in this sketch) at the front end of the eccentric shaft *D*. After passing through a screen and the pump, it is forced through a strainer *A* in the filter *E*, thence through pipes to the pump-shaft bearings, eccentric-shaft chains, and main crankshaft bearings. It reaches the crankshaft bearings through the oil inlet *F*, the drilled holes in the crankshaft being indicated at *G*. From these holes, it reaches the hollow center of the connecting rods *H*, and thus to the piston pins and piston outer walls. At the bottom of each connecting rod, there are three small radial holes through which sufficient oil escapes to lubricate the inner and outer sleeves which take the place of the valves. A gage on the dashboard, or cowlboard, indicates the oil pressure and should read from 1 to 5 pounds with the throttle closed and the motor idling, and from 40 to 60 pounds when the throttle is wide open and the motor running normally or at high speed.

Regulator Connected to Throttle. The variation on this pressure is controlled entirely by the by-pass in the main oil lead, which is connected directly to the throttle-control mechanism. This by-pass consists of a body with an oil port and a piston with a series of holes. When the throttle is closed, and the motor idling, these holes and port register, so oil passes through freely, relieving the pressure on the bearings. When the motor is speeded up and more oil is needed, the piston is turned by the throttle connection so that the holes and ports no longer register and the oil cannot escape as freely and must be forced through to the bearings. This by-pass is adjustable by means of the small blade *B*, Fig. 216, which is rotated from the center to right or left and locked by the clamp bolt *C*. The safety valve *I* within the crankcase is set at the factory for the maximum pressure to be used in the system. If this is approximated, this valve is forced open and the oil escapes back into the crankcase, thus lowering the pressure. The oil-level indicator *J* is operated through the float *K* in the oil well and indicates the quantity. In cleaning and replacing filter screen *A*, be sure the holes register. The system used on the Stearns-Knight eight-cylinder V-type motor is essentially the same, with a few differences of location due to the form of engine.

On high-speed and multi-cylinder motors (which are almost invariably high-speed forms), the lubrication assumes an importance not hitherto attached to it. This is responsible for the pressures used and for the wide spread use of mechanically driven positive pumps. Formerly, pressures of from a few ounces to 4 or 5 pounds were considered sufficient. Now, pressures as high as 60 and 70 pounds are not unusual. These tremendous pressures, however, have necessi-

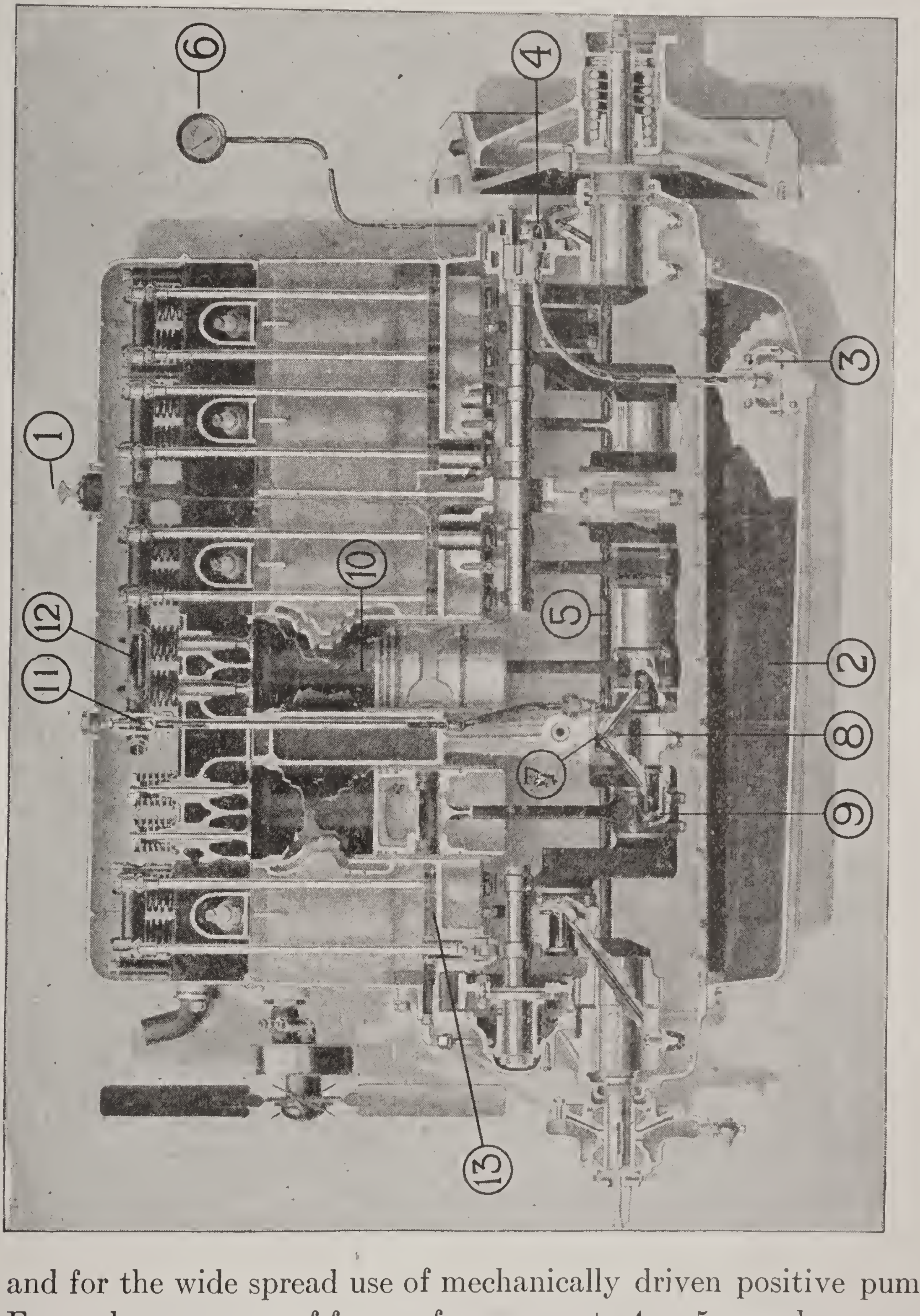


Fig. 217. Pressure System with Many Individual Features on Marmon Engine
Courtesy of Nordyke & Marmon Company, Indianapolis, Indiana

tated a system much more carefully constructed, assembled, and used than was the case previously.

Marmon. The Marmon system is not radically different from that just described, but there are a number of small individual points worthy of mention. The filling is not through the usual crankcase breather pipe, but through an opening in the top of the cylinder head *1*, Fig. 217. From this opening the oil flows around the valve push rods (the motor had overhead valves as will be noted) down into the bottom of the oil pan *2*. After screening at *3*, it passes through the throttle-controlled regulator to the oil pump *4* on the rear end of the camshaft. The main feed pipe is marked *5*, the pressure gage *6*, lead to crankshaft bearings *7*, hollow in crankshaft *8*, connecting-rod bearing *9*, cylinder walls *10*, ball check valve *11* to govern pressure in main feed pipe and excess oil through hollow rocker-arm shaft *12*, connecting to oil container *13* above valve tappets.

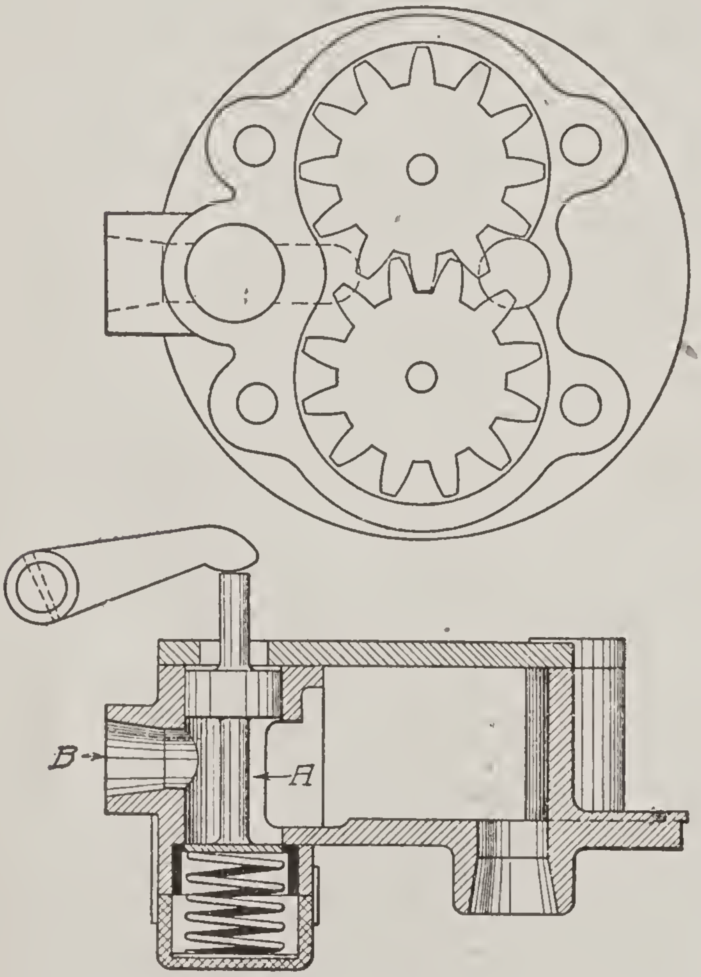


Fig. 218. Detail of Throttle-Connected Plunger in Marmon Oil Pump

In Fig. 218, a detail of the regulator is shown. Oil enters the pump body from the left through the opening *B*. The passage from *B* to the gears is controlled by the opening in the plunger *A*, which is operated by the movement of the throttle lever through the small tappet seen on top. When the throttle lever is depressed, the plunger moves down, and its upper, or piston, portion closes off a portion of the oil hole, restricting the supply. The spring under its lower extension is used to return it to position. Its shape is such that the oil has no tendency to act upon it, either to open or close it. In this system, the pressure varies from 12 to 60 pounds.

Types of Oil Pumps. There are but three or four types of oil pumps now in use, these being the gear, plunger, plunger operated by a cam, and in a few cases the vane pump. While essentially the same as the forms used for pumping water described previously, they are smaller in actual size and have some few different details. In the gear form, which is shown in Fig. 219, one gear is driven directly from the engine and, in turn, drives the other, their rotation forcing the oil along in the direction of rotation. Usually a by-pass with a check valve is provided, and when the pipe is obstructed or the pressure rises for any other reason, this opens and the oil passes around the pump at low pressure, equalizing the system.

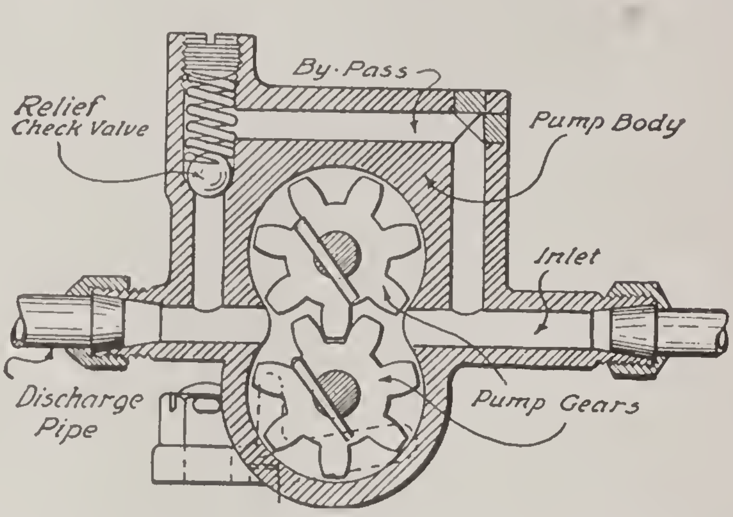


Fig. 219. Gear Type of Oil Pump of Marked Simplicity

The cam-operated plunger form is shown in Fig. 220. This is the method of drive adopted for mechanical lubricators, but few engines have an individually constructed pump of this type. It is simple, easy to regulate, seldom gets out of order and can be arranged to give a different supply at each plunger should the system warrant or necessitate this. A good example of the plunger form is the oil pump on the Reo engine, shown in Fig. 221. This works as follows: When the pump plunger *A* is moved upward by the curved eccentric *B*, it draws oil through the ports *C* and the screen *D*, as the entire lower part is submerged in the oil. When the maximum amount of oil is drawn into the pump chamber in this way, the plunger descends, the ball *E* rises, and the oil flows up inside the hollow plunger to the top ports *F*, through these to the surrounding chamber *G*, and thence to the outlet *H* and into the oil pipes. This form is very accurate and reliable.

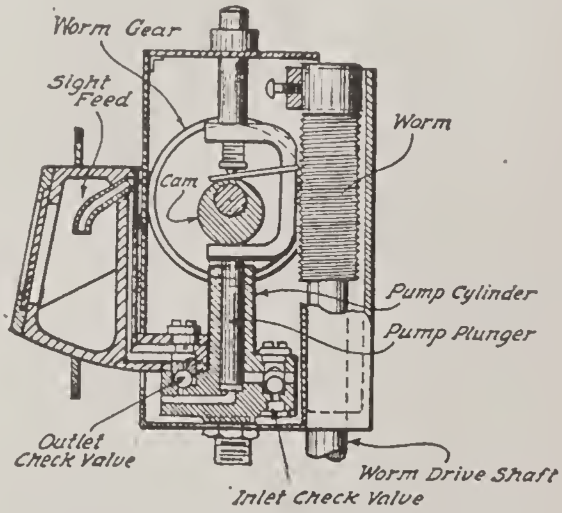


Fig. 220. Cam-Actuated Plunger Form of Oil Pump

Methods of Driving Pumps. Another point of considerable importance to the repair man is the method of driving the pump, since this influences its location and its accessibility. There are but two general methods of driving. One is by means of a special oil-pump shaft, in which the pump will quite generally be found in the bottom of the oil sump or very close to it; the other is from some part of a shaft used for other purposes, in which case the position may vary widely. Examples of the first, or special-shaft method, will be seen in Overland, Fig. 214, and Cadillac, Fig. 215. Examples of the second method are seen in Stearns, Fig. 216, and Marmon, Fig. 217, in both of which the camshaft is used.

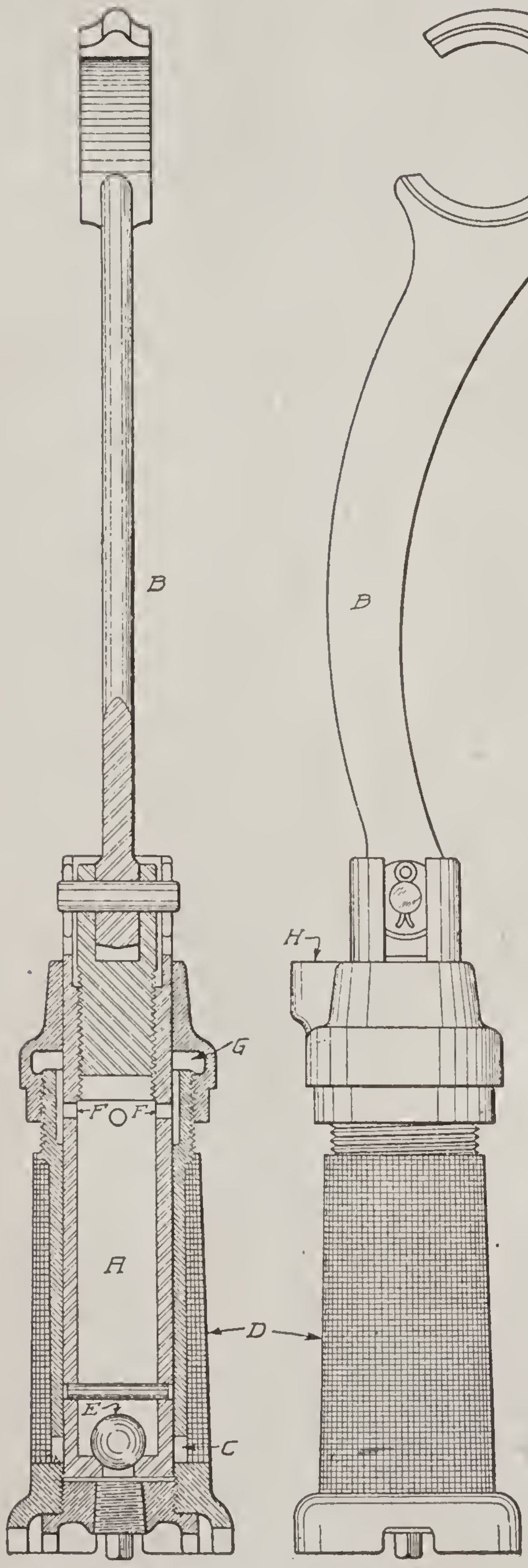


Fig. 221. Typical Plunger Pump
Courtesy of Reo Motor Car Company, Lansing, Michigan

In Fig. 222, a gear is placed directly upon the rear end of the camshaft meshing, with another, immediately below it which forms the pump. This is the Scripps-Booth eight. Attention is called to these additional points, the hollow crankshaft for oil circulation at A, the method of carrying the oil leads and regulator up to a handy point on top of the motor at B, and the air cooling flanges on the bottom of the oil pan at C. The purpose of the latter is to reduce the temperature of the oil after it has been used and returned to the oil-supply reservoir and before it has been used a second time. The oil pump on the end of the camshaft is marked D.

In Fig. 223, the oil pump is a simple plunger operated by a cam

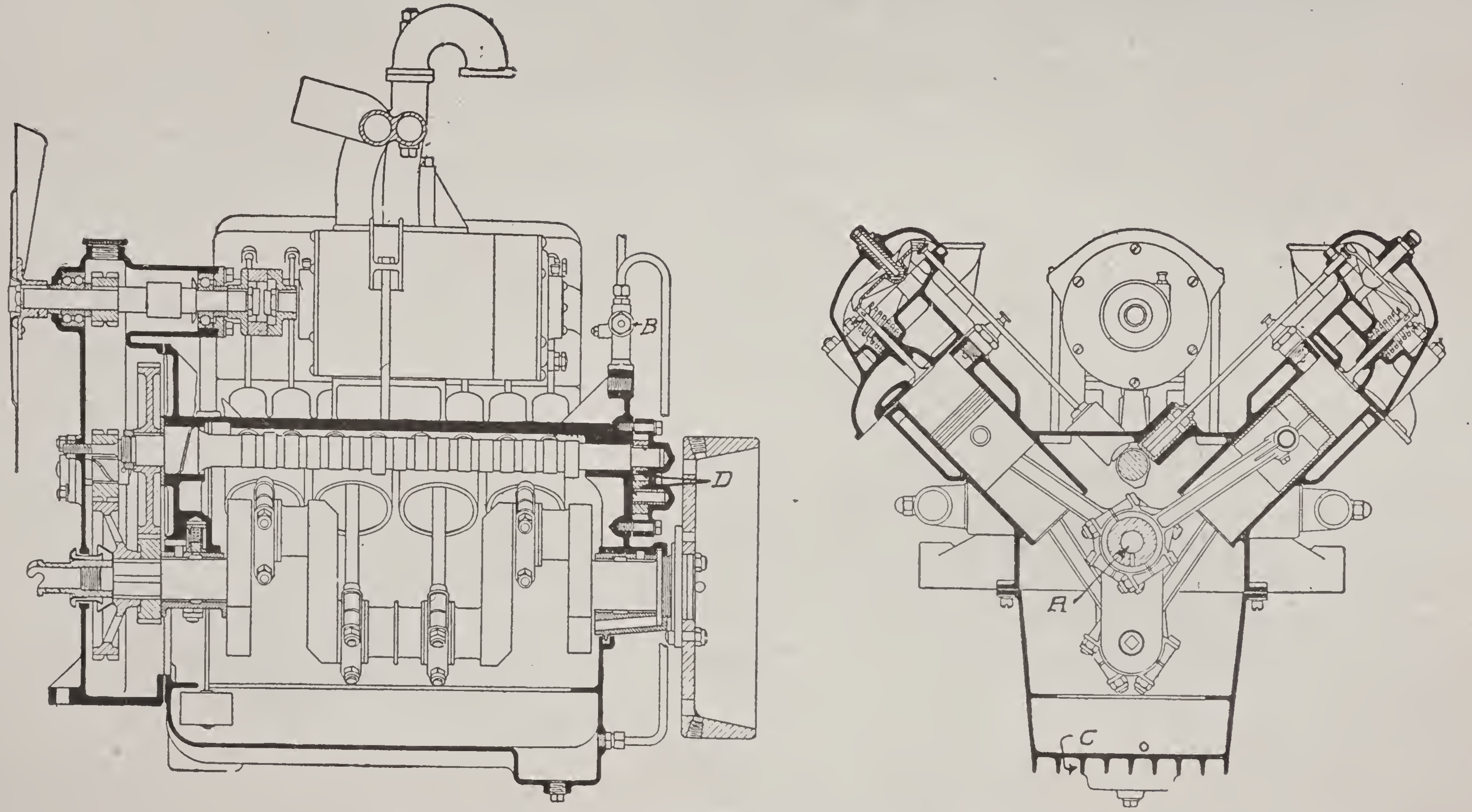


Fig. 222. Section and End Elevation of Scripps-Booth Eight, Showing Oiling System
Courtesy of Scripps-Booth Corporation, Detroit, Michigan

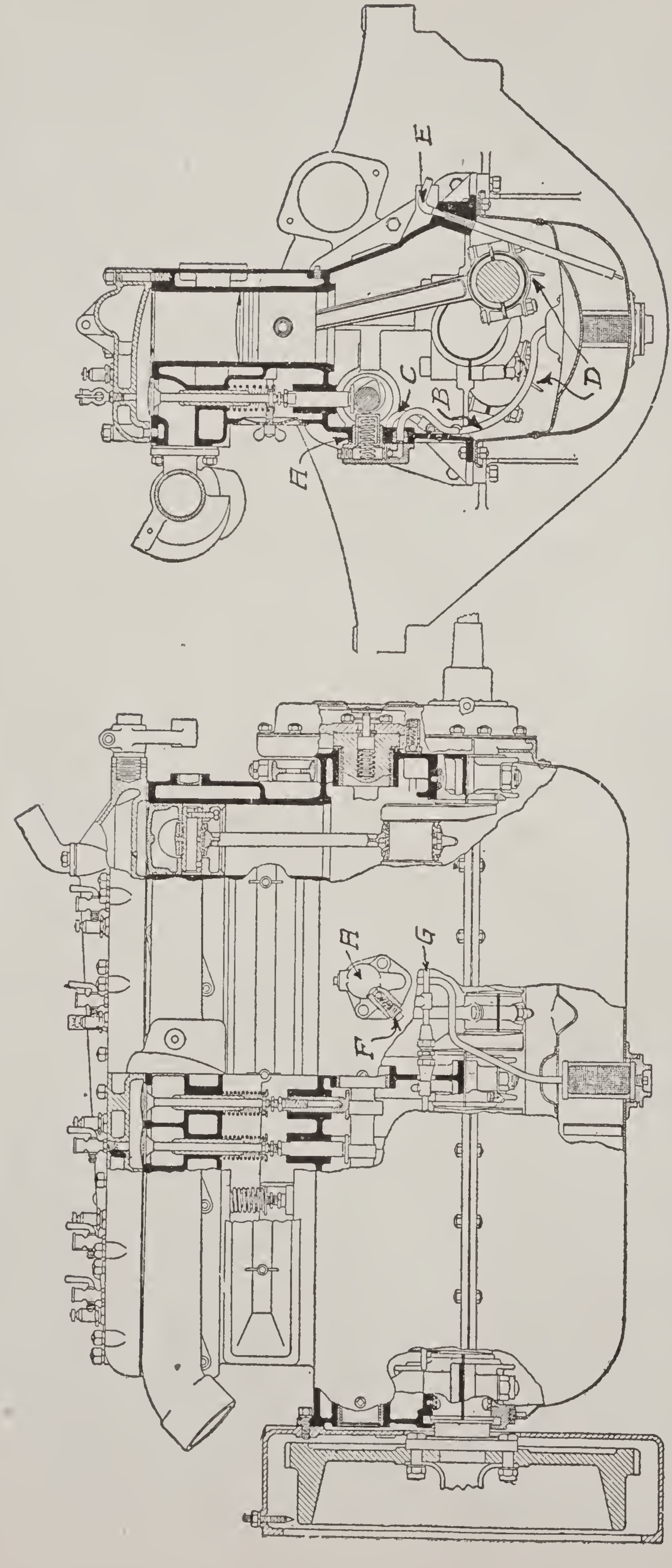


Fig. 223. Side and End Sections of Engine with Horizontal Plunger Type of Oil Pump

on the camshaft. It projects out at right angles on the side between cylinders 2 and 3. It is possible to arrange a system of this kind so that an extra cam is not needed, one of the regular valve cams doing the work of pumping the oil. This makes a simple and inexpensive arrangement. The oil suction pipe is marked *B* and the pipe carrying the supply to the bearings is marked *C*. Attention is called to the connecting-rod oil scoops *D*, the feed adjustment *E*, the pressure-relief valve *F*, and to the main oil lead *G*.

Individual Pump Pressure Feeding. The expedient of feeding the oil by individual pumps, independently driven and capable of individual adjustment which enables them to feed any desired amount of oil to any particular bearing regardless of the amount that may be fed to any other bearing, has been widely applied. In such a system, if obstruction of any one of the leads should occur, it is almost certain to be forced out by the action of the pump, which, in all lubricating systems of established type, is made capable of working against enormous pressure.

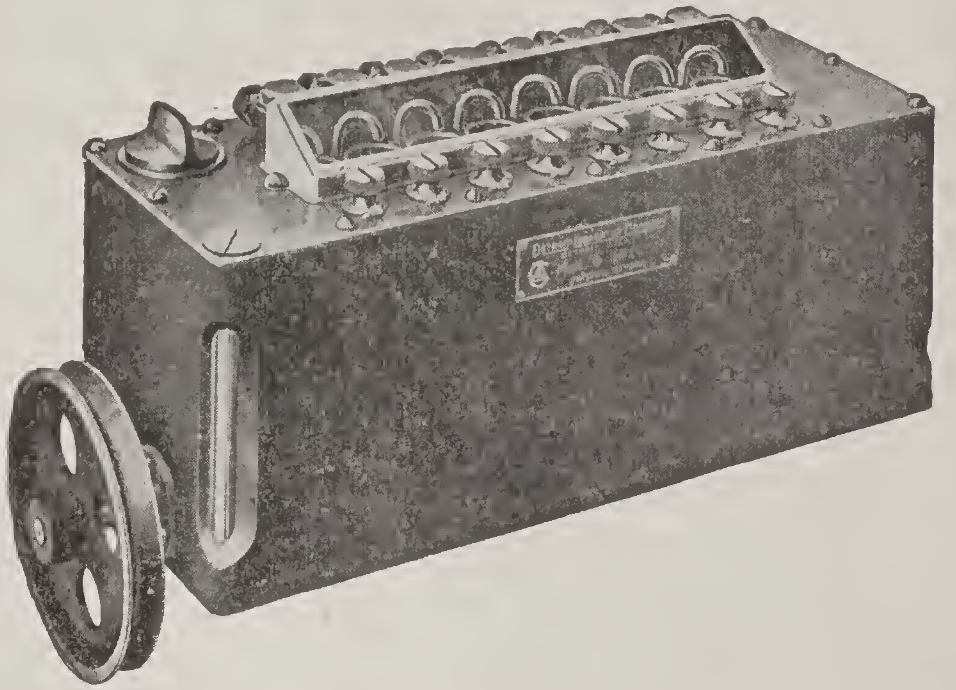


Fig. 224. Detroit Eight-Feed Multiple Oiler as Used for Motor Lubrication

Courtesy of Detroit Lubricator Company, Detroit, Michigan

One of these lubricators, made for eight feeds, is shown in Fig. 224. By extending the casing and the longitudinal shaft inside and adding more pumps, this type is capable of extension to any desired number. The eight-feed form shown allows of one lead to each of the three main bearings of a four-cylinder engine, one each to the four cylinder walls, with a lead remaining for the gear case at the front of the motor.

Gravity Feeding. Feeding of oil by gravity to one or more bearings is a method that has been employed with some success, but it is now encountered only in rare instances in automobile power plants.

Splash Lubrication. The feeding of oil to bearing surfaces by the simple expedient of enclosing a quantity of it in a reservoir in which the working parts are also contained is a successful and widely used scheme in automobile motor construction.

In the splash lubrication system, as will be shown in detail later, the lower ends of the connecting rods "splash" up the oil which is in the bottom of the crankcase in the form of a huge puddle. Since this method, formerly almost universal, has been criticised as wasteful of oil as well as productive of much needless smoke, it has been modified by the majority of makers so that the scoops on the ends of the connecting rods dip into small narrow troughs provided for this purpose. Another objection to this system is that at high speeds too little oil is thrown around the interior of the cylinders and crankcase, since the initial rotation of the rods has churned or beaten the entire supply into a mist, while at low speeds too much is thrown around for the work the engine is doing.

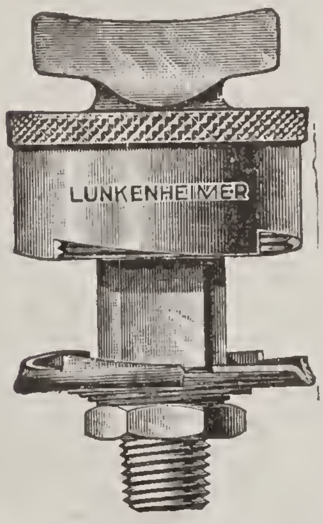


Fig. 225. Typical Screw Type Grease Cup with Wing Handle

Courtesy of Lunkenheimer Company, Cincinnati, Ohio

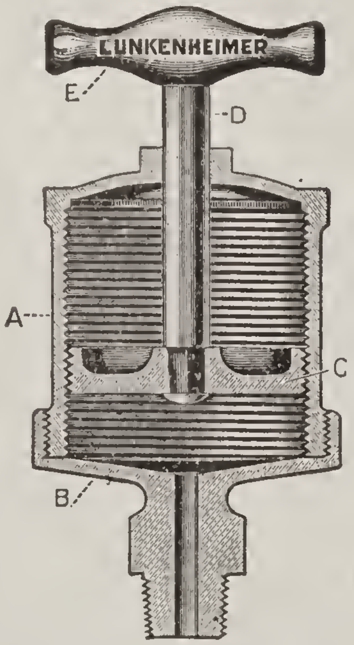


Fig. 226. Lunkenheimer Grease Cup with Removable Barrel

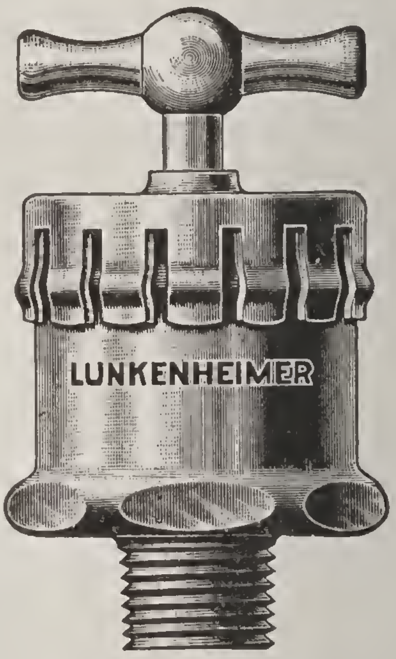


Fig. 227. Lunkenheimer Grease Cup with Spring Cover for Quick Filling

The latter objection has been overcome in the newer engines by making the troughs into which the connecting-rod scoops dip movable and attached to the throttle lever, so that when the latter is opened wide to develop maximum power, the troughs are brought up higher, allowing the scoops to dip down deeper and thus supply a greater amount of lubricant.

External Lubrication. In the lubrication of the external parts of the motor, such as the pump shaft, magneto shaft, oiler shaft, fan shaft, generator shaft, air pump shaft, etc., an entirely different method of lubrication is necessary—one that is more simple in every respect, allows the use of more simple lubricating devices, and does not require anything like the care and adjustment previously pointed out for the internal parts.

Oil and Grease Cups. Chief among the devices used for lubricating these outside parts are oil and grease cups, the oil cups being used in decreasing quantities and the grease cups in increasing quantities. Formerly, oil cups were much used, but they gave poor satisfaction, collected dirt, and were unsatisfactory generally. In the use of grease cups, there are but three things to observe: They should be large enough, accessible, and easy to fill.

For application to spring eye-bolts there is a particular type of grease cup. This grease cup is of the type that feeds by being occasionally screwed up a small distance as the bearing uses up the lubricant, and its positive action is rendered more certain by the use of a detent (not illustrated) that holds the cover in any position in which it may be left. The grease is contained in the entire cap which, when unscrewed from the lower portion, is readily and conveniently filled by scooping up the grease.

A form quite generally used is the simple cup shown in Fig. 225. This is a screw-compression cup from which the lubricant is forced out by screwing down on the reservoir. This form is prevented from coming loose by the compression spring, here shown very much compressed below the ratchet, which governs the screwing down of the reservoir. To fill the reservoir, the ratchet portion is held down and the top screwed off, turning in the reverse of the usual direction. Although the top is fitted with a wing handle, it can hardly be considered easy to refill.

Another widely used form is seen in section in Fig. 226. This has a larger handle and, in this respect, may be considered easier to fill. A type which is rapidly coming into use and has all the advantages of the other two, and more, is shown in Fig. 227. This is a plain screw type with a large handle, but the cap is of sheet brass and is sprung into place. As this is sprung off by the plunger inside when screwed away out, filling is reduced to a matter of seconds. The plunger screws all the way in and affords pressure all the way.

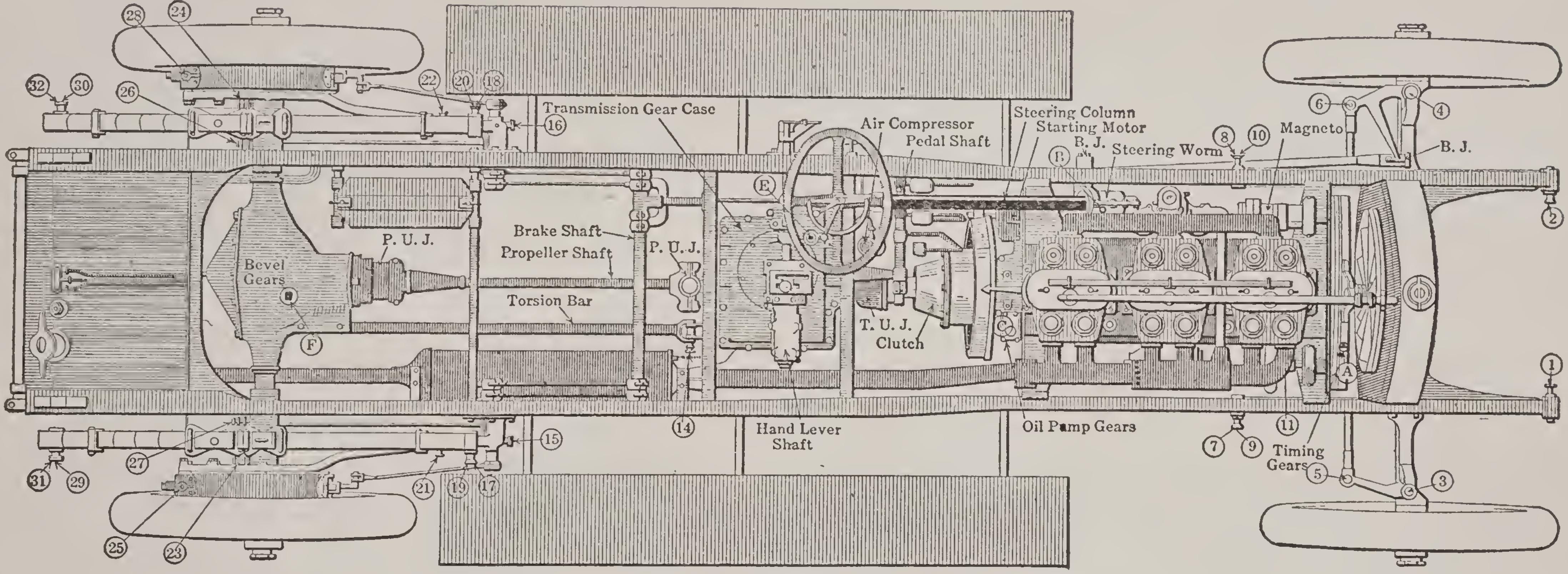


Fig. 228. View of Locomobile Chassis, Showing Complete Oiling System

Instructions as follows: Spring Grease Cups 1, 2, 7 to 10, 17 to 20, and 29 to 32 should be given full turn every day and kept filled; Distance Rod Grease Cups 15, 16, 21, 22, 23, 24, 26 and 27 should be given a full turn every other day or once in 500 miles and kept filled; Steering Tie Rod and Steering Pivot Grease Cups 3 to 6 should be given full turn every day and kept filled; Water Pump Grease Cup 11 should be turned down every day—special heavy mineral grease or beef or mutton tallow should be used in these; Torsion Bar Pivot Grease Cup 14 should be turned down once a week or every 1000 miles; Brake Shoe Supporting Bracket Oil Cups 25 and 28 should be turned down once a week; Engine Oiling System should be drained every 2000 miles and refilled through plug *A;* Steering Worm Gear Case should be filled with grease every 2000 miles through plug *B;* Oil-Pump Gear Housing should be packed with grease once a season through plug *C;* Transmission Case should have grease added, through plug *E*, every 2000 miles to bring supply up to proper level; Rear Axle Housing should be drained every 5000 miles and refilled with grease through plug *F;* Clutch Universal T. U. J. and Universal Joints P. U. J. should be packed with grease once a season; Generator, Starting Motor, Spark and Throttle Levers, Steering Column, Carburetor Regulating Collar, and Brake Shaft Equalizers should be oiled every 1000 miles; Magneto and Air Compressor should be oiled, Transmission, Steering Worm-Gear Case, and Ball and Socket Universals in Steering Connections should be greased every 2000 miles; Foot Pedal Shafts and Hand Lever Shafts should be oiled every 5000 miles or once a season; Fan Bearings, Clutch Brake Ball Bearing, and Steering Column Screw and Nut should be greased every 5000 miles or once a season.

The simplest form of oil cup has a hole in one side, which is covered with a spring-held cover. To use it, the cover is lifted with the fingers until the hole is uncovered, then the point of the oil can is inserted and the oil forced in.

GENERAL LUBRICATION

Lubricating the Whole Car. It is best for both the private owner and the repair man to have a definite regular system for going over the grease and oil cups on the chassis. As shown in Fig. 228, there are a number of cups varying from 30 to 32 and upward, as well as oil holes, which need to be looked after occasionally. The worker should get an oiling chart and fix firmly in his mind the requirements of the various parts to be oiled or greased and should regulate his oil and grease cups by hand from day to day and week to week so as to produce the desired results.

Lubrication of Other Parts. The precise lubrication of the clutch, transmission, rear axle, and other more important units will be found discussed in detail under their respective headings.

There are signs at present that the lubrication of the motor may be controlled through the medium of a thermostat in order to conserve every unit of heat needed in the vaporization of the fuel and thus increase the efficiency of the engine as a whole. There would be a double advantage in this, for lubrication would be placed on a more economical basis. In using the thermostat, smoking and carbonization would be reduced, and their heat utilized. This process, carried out to a logical conclusion, might result in forced lubrication of all points on the chassis by means of the oil-pump system. A system of forced lubrication somewhat like the above has been produced in the Fergus car, but here the idea was to reduce the amount of work in connection with lubrication. The number of points outside of the automatic oiling system, which required oil or grease application by hand, has been reduced in this car from 80 to 11. Some 18 points in the springing system have been eliminated entirely by enclosing the springs in leather boots, grooving and drilling them, and forcing oil in under pressure from the main pump. It is questionable, however, whether the results as obtained in this case are worth the cost in money and complication, for this system gives a freak appearance to the car.

Oils and Greases

Characteristics of Good Oils. The variety of oils and greases recommended for automobile use is so extensive, and there are so many cheap and worthless lubricating compounds on the market, that it is almost impossible for the purchaser without technical knowledge to discriminate between them. The various tests from time to time recommended, whereby the user may ascertain for himself the quality of the lubricant he is using, are rarely of positive value, since the compounders of the shoddy oils and greases are usually sufficiently expert chemists to concoct admixtures that will successfully pass such simple tests as are available to the average layman, and will fail only under the more critical analysis of a competent chemist, or under the severe and more risky practical demonstration that results from long use, in the course of which the worthlessness of the lubricant is likely to be found out only at the cost of serious injury to the mechanism. The consequence is that the only really safe policy to follow is the purchase of the highest grades of oils and greases, marketed by concerns of established reputation.

The oils generally found best for gasoline-engine cylinder lubrication are the mineral oils derived from petroleum, though castor oil is found to possess peculiar merits for the lubrication of air-cooled motors working at high temperatures in which the friction of steel surfaces working over steel surfaces is often involved. This oil is exclusively employed in aviation motors, such as the Gnome, which is built with steel cylinders and pistons, and it is often utilized in racing automobile motors. Its chief merit seems to be that instead of withstanding the high temperatures, which is the result sought in the use of mineral oils of high fire test, it burns up clean without leaving any deposit upon the cylinder walls. It has to be fed in excessive quantities, which makes its use a rather expensive method of lubrication. But for the peculiar services for which it is adapted, it certainly proves most satisfactory.

In greases and oils used for the lubrication of parts not exposed to such high temperatures as prevail in gasoline-engine cylinders, the admixture of vegetable and animal greases and oils with mineral oils and greases is not objectionable and often may be of considerable benefit.

Graphite is a solid lubricant and is very advantageous to employ in many parts of an automobile. In the deflocculated form, admixed in very small percentages with cylinder oils, gearbox greases, etc., there is no question but what it greatly conduces to smooth running and to long life of bearings. Its resistance to the very highest temperatures makes it constitute a considerable safeguard against immediate injury in case of neglect to replenish the lubricants as often as is properly required.

Testing Oils for Acid, Etc. Oils must be purchased with much care. Once an oil is found which does the work satisfactorily, it should be adhered to consistently. No two oils are exactly alike, and for that reason, no two will do the same work under the same conditions in the same way. So, it is advisable to experiment only until an oil is found which will do the work. Thereafter, stick to that brand. As an instance of the impurities which may be found in oils, acids may be mentioned. These are fatal to delicate and closely machined parts, such as ball bearings, cylinder walls, pistons, etc., and consequently they should be watched for.

Pure mineral oils contain little acid, and what they do contain is readily determined. Vegetable and animal oils, on the other hand, all have acid content and under the action of heat this may be liberated. A simple home test may be practiced as follows: Secure from a druggist a solution of sodium carbonate in an equal weight of water. Place this in a small glass bottle or vial. To test an oil, take a small quantity of the lubricant and an equal amount of the sodium solution. Put both in another bottle, agitate thoroughly, and then allow it to stand. If any acid is present, a precipitate will settle to the bottom, the amount of the precipitation being a measure of the amount of acid present.

Another method is to allow the acid, if there is any, to attack some metal. To do this proceed as follows: Soak a piece of cloth or, preferably, wicking in the oil suspected of containing acid. Select a piece of steel at random and polish it to a bright surface. Wrap the steel in the soaked rag or wicking, and place in the sunlight but protect it from wind or weather. Allow it to stand several days, and if there is no sign of etching of the surface, repeat with a freshly soaked rag, being careful to use the same oil as before. After two trials, if no sign of the etching appears, you may consider it free from acid.

Principles of Effective Lubrication. To render lubrication positive and effective there are certain conditions regarding the design of bearings and the feeding of lubricants that must be scrupulously observed.

The proper application of a lubricant to a revolving shaft passing through a bearing requires that definite space be provided between shaft and bearing for the lubricating material. The amount of this space varies with the size of the shaft, the speed of rotation, and other conditions, but in a general way it can be specified that the space must be greater as the shaft diameter increases, and greater for heavy oils and low speeds than for light oils and high speeds. For the crankshafts of automobile engines, to take a specific example, it is rarely desirable to have the bearing smaller than from .0005 to .0015 inch larger than the shaft. The annular space thus provided, as suggested at *A* in the end and sectional views in Fig. 229, is occupied by the lubricant, which, contrary to another general impression, will not be squeezed out unless the shaft is loaded above its capacity; this is more likely to occur because the bearing area is too small than from any other condition likely to be encountered.

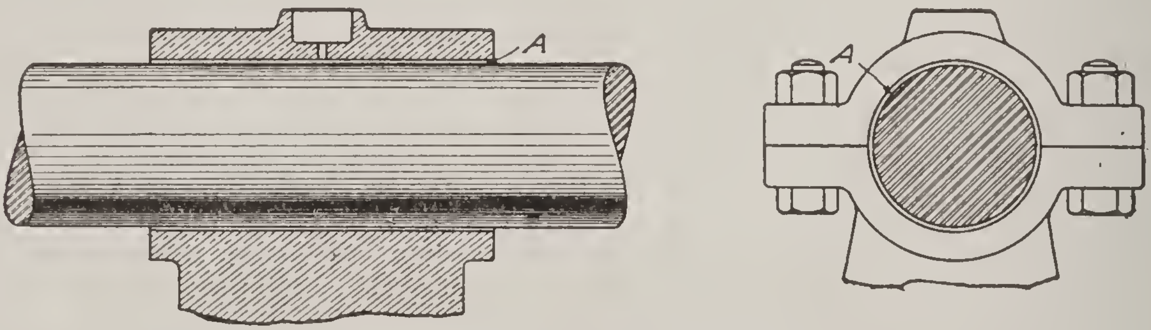


Fig. 229. Condition of Bearing for Proper Lubrication

With the bearing area large enough—which means that the specific pressure on its projected area must not be excessive—the tendency of the oil to remain in its place by capillary attraction, perhaps helped by the pressure under which it is fed into the bearing, is much greater than the tendency of the load upon the shaft to force it out.

From the foregoing, it is evident that the condition of effective lubrication is that in which the shaft literally floats in an oil film of microscopic thickness, this film completely surrounding it and so protecting it from any contact whatever, under normal conditions, with the bearing surface. The necessity for the accurate fitting of bearings is not to secure a close metal-to-metal contact, as is sometimes erroneously supposed, but to provide an oil film of the necessary uniform, instead of an irregular, thickness.

LUBRICATION TROUBLES AND REMEDIES

Care of Lubricant in Cold Weather. Nearly everyone realizes the amount of care necessary with cooling water in freezing weather, but few realize that extreme cold has practically the same effect upon lubricants. In the coldest weather, a lighter grade of oil specially made to withstand low temperatures should be used. If a special oil cannot be obtained, the lighter thinner quality will suffice, as even when thickened up by the low temperatures this oil will flow more readily than the thick oils. Sometimes the slow circulation of the oil in cold weather allows the motor bearings to run dry and heat. This trouble can be remedied by changing to a lighter oil. The same is true of the clutch oil which is in the multiple disc running in oil. Thick oil in this in cold weather will often thicken up and stick so the clutch will not work well.

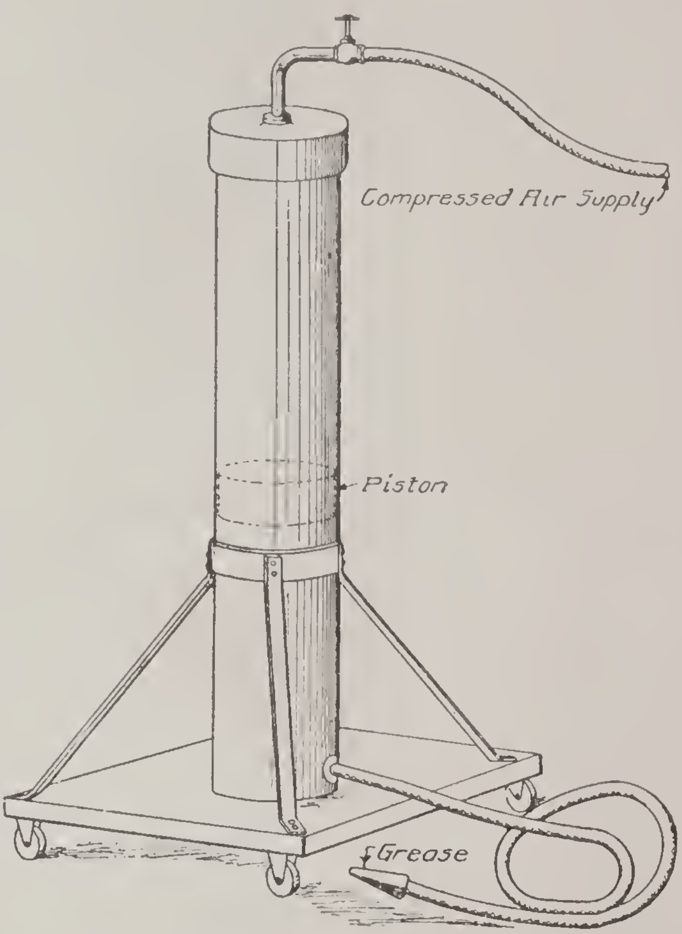


Fig. 230. Mammoth Grease Gun for Garage Use
Courtesy of "Motor World"

Mammoth Grease Gun. For the average shop which handles a good many cars a day, too much time is wasted in using an ordinary method of filling a transmission, rear axle, or other large part, with grease. A mammoth grease gun can be constructed to do this same work in a few seconds. A form operated by compressed air is shown in Fig. 230. It consists of a steel cylinder about 8 inches in diameter and perhaps 7 feet long mounted vertically on a platform which is set on castors so that it can be wheeled around the shop as needed. A free piston is placed in the cylinder, above the grease, and air admitted through the central opening in the screw top by screwing on a compressed air hose. The outlet hose at the bottom is made long enough to reach any ordinary point on the average car. When a transmission is to be filled, the platform is wheeled up to the car, the bottom hose put in the transmission, and the cock opened. Then the air hose is connected and the pressure turned on; the grease will be forced out in a hurry, filling the case in a few minutes regardless of the quantity needed. A somewhat similar device can be made in a smaller size. This device is almost an exact copy of the ordinary hand grease gun, but it has a rod, threaded through the cap, which operates the plunger. One man can hold the gun while another turns the handle, which forces out a tremendous quantity of grease in a short time.

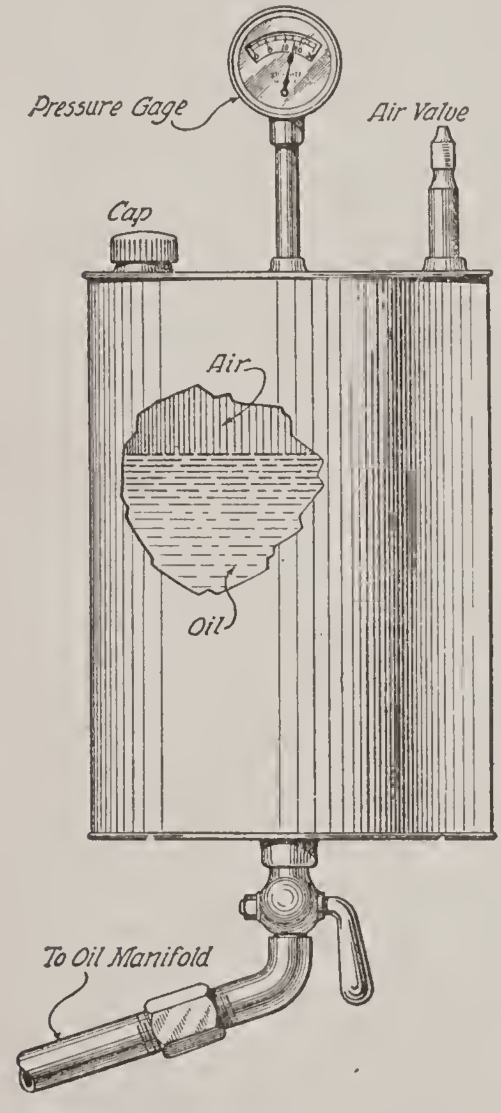


Fig. 231. Pressure Outfit for Testing Loose Bearings
Courtesy of "Motor World"

Oil Tank and Outfit for Testing Bearings. A tank for testing the leakage of bearings, particularly engine bearings that are loose, may be constructed by fixing in the top of a small tank a gage which will read up as high as 20 pounds, an inner-tube valve stem for supplying and holding air pressure, and a filling cap which is air tight; at the bottom of the tank an outlet is placed which is controlled by a valve or cock. This outfit, as shown in Fig 231, is partially filled with oil. Air is then pumped in, and the connection is made into the oiling system after the removal of the oil pump. The gage will indicate the pressure at which the oil is being pumped through, and the leakage of the oil around the bearings will show their looseness. Close-fitting bearings do not leak.

Getting Oil Barrels Out of Sight. The oil barrels around the garage are in the way; they collect dirt and spread oil into everything within reach and take up much valuable space. A good way to get rid of them is to build a rack close to the ceiling, as shown in Fig. 232, and put them up there. A pipe with a faucet at its lower end for drawing oil leads down from each barrel; these pipes are grouped over a small pan which catches the drip. Filling these barrels is easier than it seems. Simply connect a pipe from the barrel of new oil to the overhead barrel to be filled, apply the air pressure carefully at the bung, and the oil will be forced up.

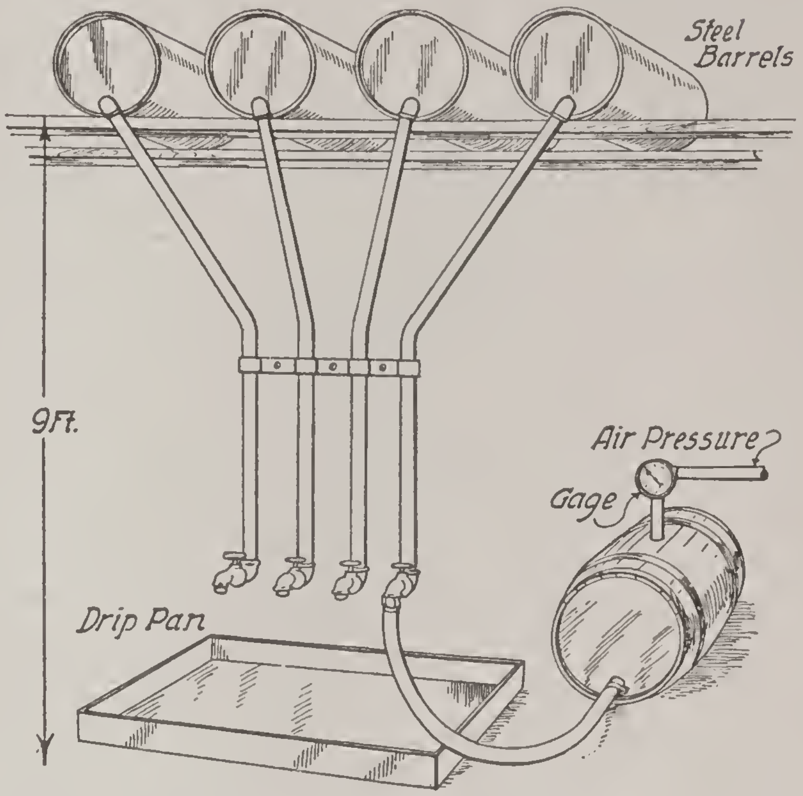


Fig. 232. Method of Elevating Oil Barrels to Save Space
Courtesy of "Motor World"

A more simple method of covering and protecting the barrels is to have a box, or stand, large enough for three or more barrels, made from light lumber. Then bore a small hole, at the place where each barrel will stand, for the faucet, as Fig. 233 shows. Generally, three barrels will be sufficient, as one for heavy oil, one for light oil, and one for kerosene will cover all ordinary work. The shelf which holds the various measures should be attached to the frame.

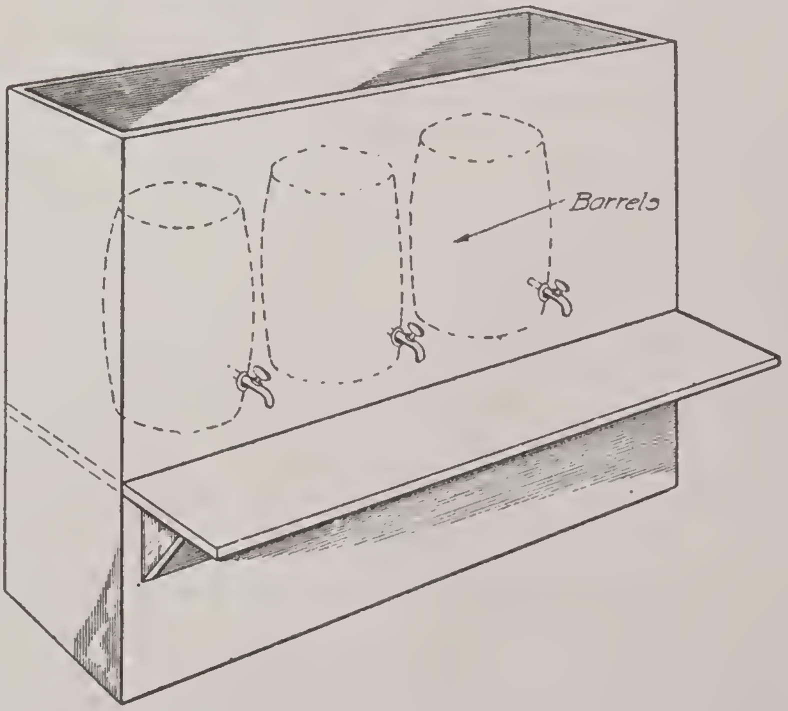


Fig. 233. Easily Constructed Box for Concealing and Protecting Oil Barrels
Courtesy of "Motor World"

A convenient oil-drain rack in the form of a small square box, say 6 to 8 inches deep, can be made with tin. Punch a series of small and medium size holes in the top of the box. When the funnel has been used for filling an oil tank or measure, it can be placed in the rack and allowed to drain. In this way, oil waste is minimized and the place is kept free from oil drippings, which soon gather dust and then are tracked into office and customers' cars.

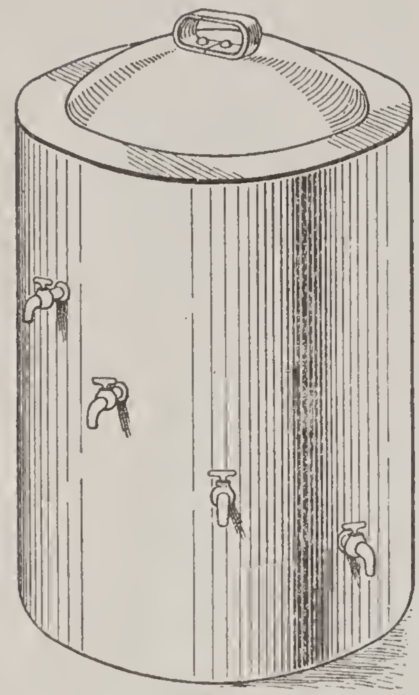


Fig. 234. Settling Tank with Cocks at Various Levels for Saving Oil

Oil Settling Tanks. If lubricating systems are drained as often as both manufacturers and oil people recommend, there is a good deal of oil around, which is heavy and of a doubtful quality. But if this oil can be allowed to stand, or can be filtered, a large quantity of it can be used for other purposes. If a tank of fairly large size is made with a series of faucets or cocks at different levels, somewhat like that shown in Fig. 234, enough of the oil can be saved to resell at a good profit, or, if there is no idea of selling it, it can be used for other machinery or for other purposes, where the need for high-quality oil is not so great. The oil drawn off the crankcase is poured in at the top and gradually settles, the heavier sediment going to the bottom, the thickest oils next, and so on, until the top will show a fair quality of light oil, and the layer next to it a fair quality of medium oil, and so on down to the bottom.

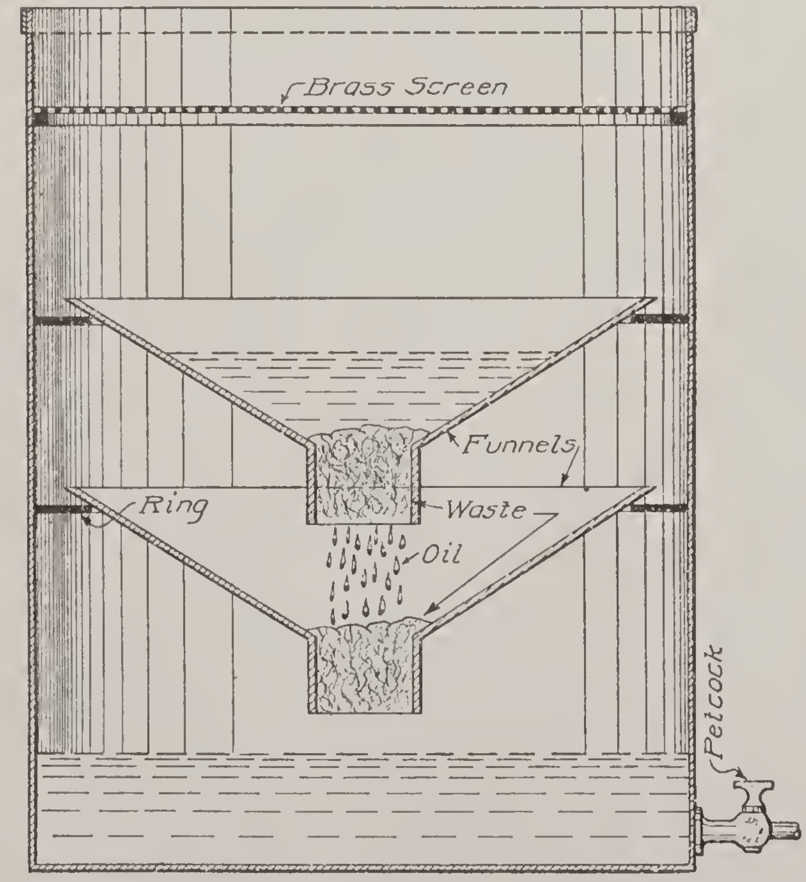


Fig. 235. Filter of Simple Construction for Filtering Oil

Oil Filtering Outfit. If one has the apparatus, filtering is much superior. A simple filtering outfit is shown in Fig. 235; this consists of the tank with provision around the inside for supporting a fine brass screen and two or more funnels, one above the other. The mouth of each of the funnels is filled with cotton waste, and the funnel set in place, then the next one is filled and set above it, and finally, the brass gauze is laid across at the top. As the oil is drawn off, it is poured in at the top. The wire catches any large particles, while the oil in filtering through the two or three bunches of waste will lose practically all its impurities, coming out perfectly clear. After each use, the waste is removed and burned, and new waste put in its place.

Oil measures, funnels, and other containers should always be kept clean. The oil left on them soon collects dust and dirt, and the next time some of this old oil will be poured into the engine with the fresh oil. All oils do not mix, and chemical action may be set up between old oil of one quality on the can and new oil of another quality in the can. Kerosene or a little gasoline should be poured in the containers or funnels to clean them off. This liquid should be rinsed out of the cans and put into a settling or filtering tank and practically all of it recovered.

Bending Oil Pipes. Frequently an oil pipe which has a curve or spiral in it, or even a series of coils has to be replaced. If bent by hand, a kink may be made in the pipe which will lead to a future break. A simple fitting for bending these pipes can be made in a few minutes. Take a piece of hard wood about 3 inches square and 9 inches long and turn it up round in the lathe, then down one end, as shown in Fig. 236, and cut the spiral grooves or threads in it. These should be about $\frac{5}{16}$ inch in width and cut with a round-nosed tool so as to get a smooth bottom to the grooves. When a pipe is to be bent, fill it with resin, a fine lead rod, or anything flexible. The wood can be held in the side of the vise and the tubing wound onto the threaded end. If the pipe is of a heavy gage, anneal it by heating and plunge it into cold water before starting to bend it. After bending, melt out the filler.

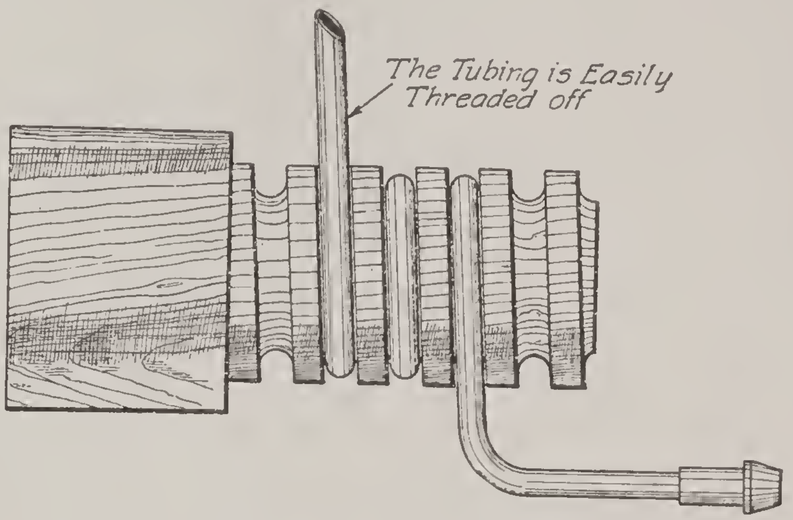


Fig. 236. Hard Wood Fixture for Bending Oil Pipe

Summary of Troubles with Lubrication Systems

Crankcase Oil. This should be changed about every 500 miles as, by this time, the lubricating qualities of the oil are nearly exhausted. After draining the oil, wash out the crankcase with kerosene and see that the kerosene is removed before putting in fresh oil.

Grease Cups. These are usually located on the rear axle, steering knuckles, steering-column base, and many other parts. They should be kept constantly filled with cup grease. These grease cups should not be confused with small oil holes having caps which can be raised but not unscrewed. Grease cups should be screwed down occasionally in order to force the grease down to the bearing surface.

Neglect of Lubrication. Neglect of lubrication is responsible for many troubles. Any automobile requires careful attention to its lubricating system. The owner will find it to his advantage financially to see that all necessary parts are properly lubricated.

Steering Gear. The steering-gear parts require occasional lubrication. These parts include steering rod; worm, or sector, and gear; steering link at both ends; foot-pedal pivot or bearing; and all joints.

Too Much Oil in Crankcase. Usually drain cocks are provided in the crankcase and are so located that when they are opened they will drain off only the surplus oil.

Troubles with Mechanical Lubricator. If one of the sight feeds fills with oil, it indicates too rapid feeding of oil. Shut off the valve on the top of the lubricator till the glass is clear. If it does not clear up shortly, the probability is that it is necessary to clean the lubricator.

Mixing Gas-Engine Cylinder Oil with Fuel. This is advocated by the makers of a few two-cycle engines, the proportion being one-half pint of best gas-engine cylinder oil with every five gallons of gasoline. This, however, is not considered good practice.

BEARINGS

Types of Bearings Required for Different Locations. As the portion of a mechanism upon which, more than upon any other element, its continued operation and long working life depends, the bearings of any piece of machinery should be of the most approved design and most perfect construction. The crankshaft and connecting-rod bearings, which are the most important on the motor, are of the plain type on the majority of engines. Of the 1914 cars but six different makes had ball bearings for the motors, and, of these, two used plain bearings on some models, so that only four makers actually believed in ball bearings for engine shafts. For camshafts there is more difference of opinion, while on fan shafts almost all makers use ball bearings. The other shafts, as pump, oiler, magneto, air-pump, generator, etc., are generally of the plain, solid, round type.

Engine bearings, however, are generally of the split, or halved, type, the upper and lower halves being practically duplicates. A reason for this construction appears as soon as one considers the application of the bearings to the shaft. It is granted that a crankshaft must be as firm and solid as possible, and hence it must be made in one piece. As ball bearings also are made in one piece, there arises at once the difficulty of getting the bearings into place on the one-piece shaft. This difficulty has necessitated cutting the shaft or else making it especially large and heavy in those cases where balls are used. With the split type of bearing there are no troubles of this kind and the bearings are adjustable for the inevitable wear.

Plain Bearings. The conditions that determine the proper proportioning and fitting of plain bearings have already been referred to in a preceding paragraph.

The materials of plain bearings are commonly varied to meet different conditions. With liberal bearing areas, in situations where it is desired to bring about a perfect fit with the minimum amount of labor, and to protect the shaft from wear in case there is failure of the lubrication, the various types of babbitt metal—which usually are alloys of tin and lead, with sometimes some admixture of antimony and other alloys—are widely regarded as the most serviceable. Probably the greatest advantage of a babbitted bearing is that, if the lubrication should fail, the low melting point and the soft material of the bearing will insure its fusing out without injury to the more expensive and valuable shaft.

Brass and bronze bearings, particularly the phosphor bronzes and the bronzes in which the proportion of tin is high and that of copper low, with sometimes the admixture of a proportion of zinc or nickel, will allow the use of materially higher pressures per square inch than can be safely permitted on babbitted bearings.

Steel shafts in cast-iron bushings, and even in hardened-steel bushings, make much better bearings than one might think, and though immediate trouble is to be anticipated with such a bearing should its lubrication fail, even momentarily, this trouble is more or less true of any bearing that can be devised. Since steel-to-steel and steel-to-cast-iron permit much the highest loadings per unit of area that are permissible with any type of metal-to-metal bearing, the merits of these materials are perhaps less appreciated than might be desirable. Steel pins through steel bushings, however, are not an uncommon construction for the piston-pin bearings in high-grade engines.

One noticeable feature of plain bronze or other plain bearings for automobile use is that they are always grooved for oil circulation. This is done by easing off the edges, then cutting a spiral groove by hand diagonally across to the other edge or to the center point where a similar groove from the other side is met. In a solid bearing, the groove is generally cut both ways from a centrally drilled oil hole, while in split bearings the grooves in each half usually form a modified letter x when viewed in plan, that is, two grooves start spirally inward from each edge near the ends, and all four meet in the center. This central point may be the spot where the oil enters or where it leaves. These grooves are seldom of very great depth, perhaps .008 to .010 (eight to ten thousandths).

New Oilless Bearings. A form of bearing that is new to the automobile but old in years is now coming into use. This is made of special wood which previously has been impregnated with oil. By saturating the pores of the wood with oil in this way, it is claimed that no lubricant need be used on the bearing for years. They are turned and fitted the same as bronze or other bushings.

Another oilless bearing is made of bronze with graphite inserts; this bearing is sufficiently soft to form the lubricant, yet sufficiently hard to retain its form and shape. Approximately one-half of the inner surface of the bearing is graphite, the two alternating in various ways, that is, the graphite is put in in spirals, in circles, in double diagonals, in a herringbone pattern, in zigzags, and otherwise.

Roller Bearings. Roller bearings, constituted by the interposition of a number of small rollers between shafts and casings, are a type of bearing widely employed in automobiles.

A much-favored construction is the tapered roller bearing illustrated in Fig. 237. This stands up very well under both thrust and radial loads.

Another type of roller bearing is that illustrated in Fig. 238, which is the type used on the Ford rear axle. This is one in which the rollers are small flexible coils made of strip steel, finally hardened and ground accurately to size. This type of roller can be depended upon to work without breakage or injury even though there be considerable deflection or inaccuracy in the alignment of shaft or casings, the flexibility of the individual rollers taking care of such small errors.

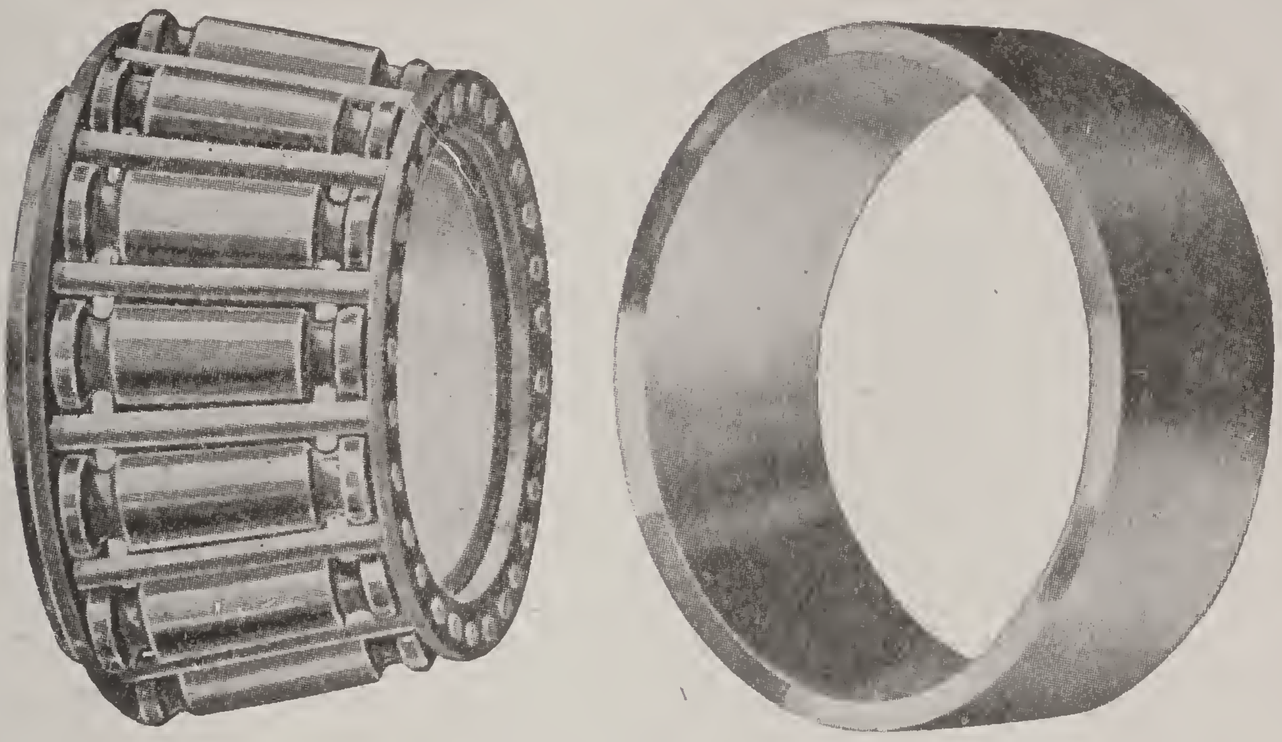


Fig. 237. Timken Roller Bearing
Courtesy of Timken Roller Bearing Axle Company

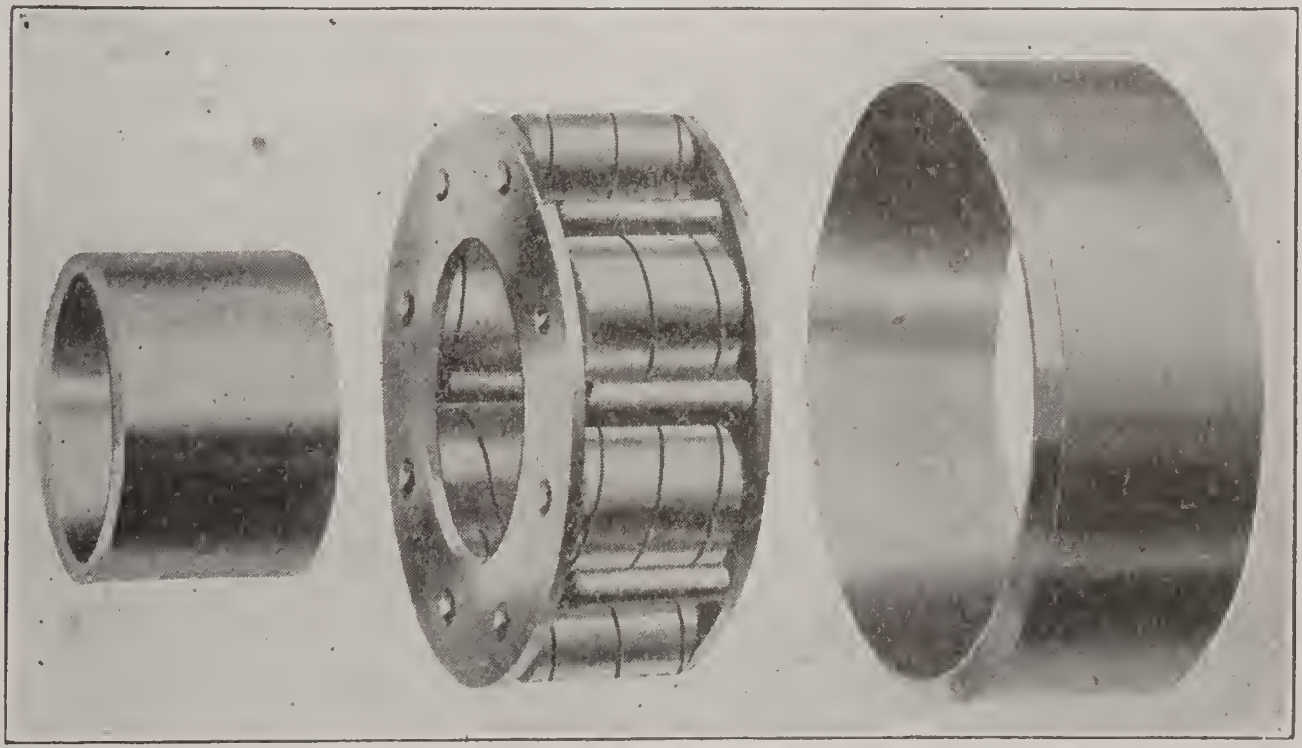


Fig. 238. Hyatt Flexible Roller Bearing Partly Disassembled to Show Components
Courtesy of Hyatt Roller Bearing Company, Newark, New Jersey

It will be noted in Fig. 238 that there is a solid steel shell to go on the shaft and fit it tightly, and another to fit into the case or support, whatever it may be, perhaps attached there permanently. Between these two comes the cage carrying the flexible rollers. Any load imposed upon the shaft is transmitted to the inner sleeve and by it to the flexible rollers; these rollers absorb the load so that none of it reaches the outer case. Furthermore, shocks coming to the case from without are absorbed by the flexibility of the rollers and, *vice versa,* shocks to the shaft do not reach the case.

Ball Bearings. Probably the best of all bearings, except for certain special applications in which it is difficult to utilize them in sufficiently large sizes to assure durability, are the annular ball bearings of the general type illustrated in Figs. 239 to 243, inclusive. The basic feature of the most successful of modern annular ball bearings is their non-adjustability, the balls being ground very accurately to size and closely fitted between the inner and outer races so as to allow practically no play.

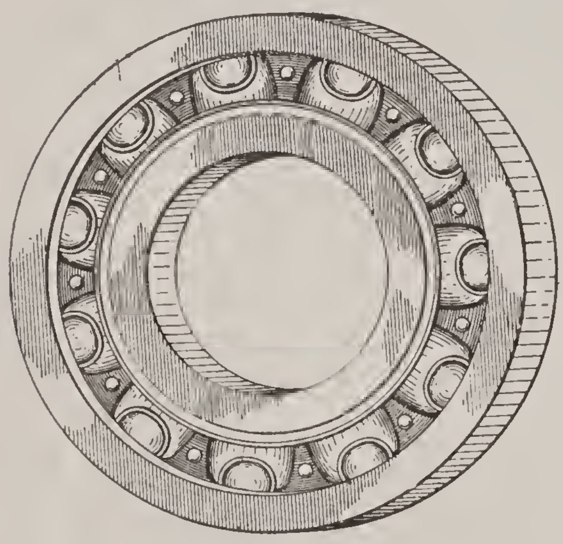


Fig. 239. Annular Ball Bearing

The reason that the best ball bearings are not made adjustable is that in any conceivable type of ball bearing one or the other of the races rotates and the other remains in a fixed position. The result is that there must be a loaded side to the race that does not rotate, with the consequence that when wear occurs, it wears the ball track deeper at this point than on the unloaded side. With the bearings thus worn, it is almost impossible to make an adjustment, for the attempt can result only in tight and loose positions as the balls come out and in of the spot that is more deeply worn.

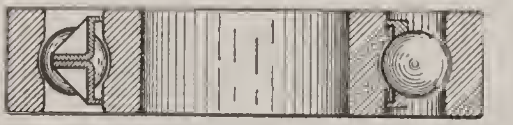


Fig. 240. Section of Annular Ball Bearing

This condition has led the designers and manufacturers of the various types of high-grade annular ball bearings that are now on the market to discard adjustment as of no value and to substitute in its place qualities of material and hardness of surface which, in combination with the provision of sufficient sizes, are found to reduce wear to so small an amount that it is almost inappreciable. A bearing thus made can be therefore depended upon to outlive almost any other part of the mechanism in which it is placed.

The carrying capacities of ball bearings, as compared with those of roller bearings, are much greater than a casual consideration might lead one to suppose. Theoretically, the contact of a roller bearing—between a roller and one of the races—is a line contact, while that between a ball and a ball race is a point. But, practically, since some deformation occurs in even the hardest materials under sufficient load, the line contact in the roller bearing becomes a rectangle and the point contact in the ball bearing becomes a circle. Now the vital fact is that the area of the rectangle in the one case is substantially equal to that of the circle in the other—with given quality of materials and a given loading. So a ball bearing is fully as capable of carrying high loads as a roller bearing; besides, it avoids the risk of breakage that usually exists with rollers because of the impossibility of making them perfectly true and cylindrical.

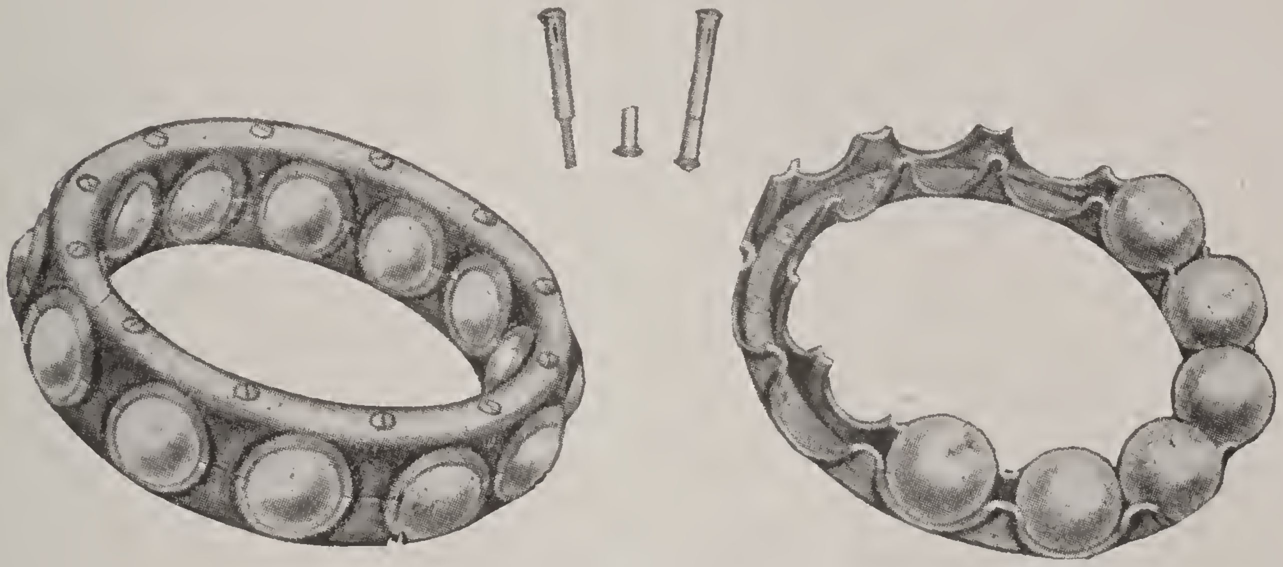


Fig. 241. Ball Cage of Annular Ball Bearing

To assemble ball bearings of the type illustrated in Fig. 240, either of two expedients may be adopted. One is to notch one or both of the ball races, so that by slightly springing them a full circle of balls can be introduced through the notch. The other scheme is to employ only enough balls to fill half of the space between the races, which permits them to be introduced without any forcing, after which they are simply spaced out at equal intervals and thus held by some sort of cage, or retainer, such as is illustrated in Fig. 241.

Ball bearings of the common annular type are quite serviceable to sustain end thrust as well as radial loads. For the best results under such loads, however, it is essential that the load be distributed equally around the entire circle of balls, for which reason the system illustrated in Fig. 242 is a means of avoiding the unequal distribution of pressure likely to result from the slightest inaccuracy of fitting. In this construction the outer ball race, shown at *A*, is provided with a spherical outer surface, permitting it to rock slightly in the mounting *C*, into the position shown in an exaggerated degree at *B*. It thus floats automatically to a position at exact right angles to the shaft upon which it is mounted, and so insures even loading of the whole ball circle.

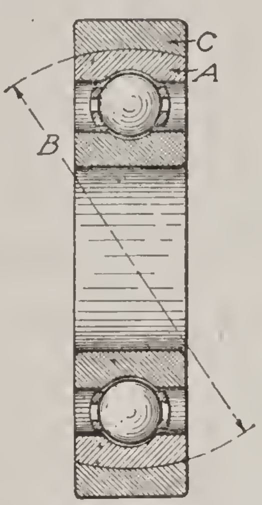


Fig. 242. Bearing Designed to Equalize Loads

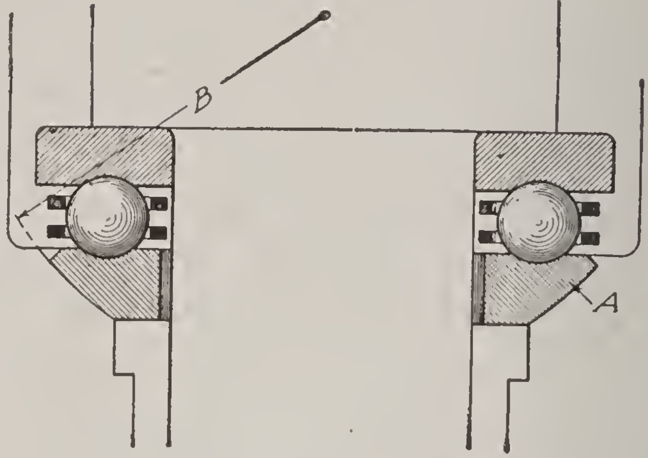


Fig. 243. Annular Ball Bearing Mounted for Thrust Loads

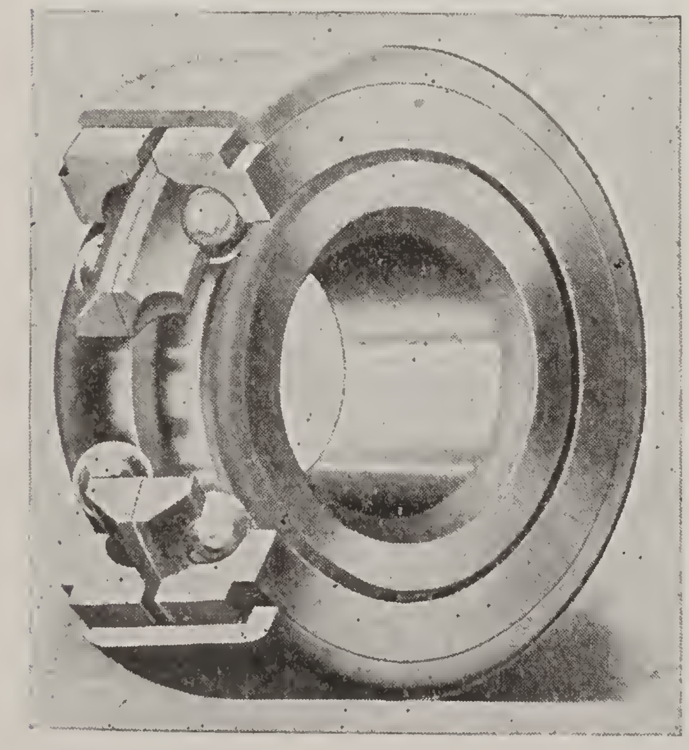


Fig. 244. Bearing for Combined Radial and Thrust Loads
Courtesy of New Departure Manufacturing Company, Bristol, Connecticut

An annular ball bearing designed for thrust loads alone is illustrated in Fig. 243. In this bearing, the lower race *A* is provided with a spherical face, described from the radius *B*, so that, as in the case of the bearing illustrated in Fig. 242, when in use it automatically floats under the load into such a position that all the balls are under equal pressure.

To secure uniformly satisfactory results from ball bearings, it is not only necessary in the first place to have them of the best materials, accurately made, and of sufficient sizes, but thereafter they must be always protected from dust and grit and from water and acids which tend to cause rust. They must also be kept lubricated,

Combined Radial and Thrust Bearing. The need for a bearing which would take ordinary radial loads well and also sustain thrust has led to the development of combined radial and thrust bearings, one being illustrated in Fig. 244. This is constructed to take either form of load equally well, and for this reason has displaced a pair of ball bearings in many circumstances where formerly it was thought necessary to use a radial ball bearing to sustain the load and a thrust ball bearing to absorb the end thrust. In this way it represents an important economy. Furthermore, it is economical of space, as it takes less room than the former pair of bearings used for the same two purposes.

FLYWHEEL SUB-GROUP

Importance of Flywheel. With the growing tendency toward smoother and more even running and the demand for lower low speeds and higher high speeds, the flywheel, which was looked upon as a necessary evil for many years, is now receiving more attention. The designers realize that the flywheel plays an important part in balancing—that if it is too heavy the engine will be slow to pick up speed and will not run very fast, and that if it is too light, the engine will be very "touchy" and will not withstand quick variations from high to low or low to high speed, nor will it throttle down very slowly.

Flywheel Characteristics. *Weights.* With weights being reduced to the limit in order to get higher engine speeds, the flywheel has received some paring down. Formerly, designers erred if at all on the heavy side with flywheels, but when they began changing the entire design of the engine to save a few pounds, they did not overlook the flywheel. In the flywheel, too, the growing use of counterweights has had an influence.

Sizes. Designers realize, now that the hampering sub-frames are out of the way, that the larger the diameter the better the flywheel effect for equal or less weight. As a result, many flywheels have been increased in diameter as they have been reduced in weight.

Shapes. Flywheel shapes, that is, sections, used to be rectangular or almost square, with a solid web or spokes practically in the center. Clutches, starter-ring gears on the outer surface, and other contributing causes have changed the character of flywheels so that few have the rectangular shape or character now. The method of using fan blades as flywheel spokes has also fallen into disuse; although at one time it was widely tried and appeared to be a means of eliminating the fan entirely.

Something of the present shape of flywheels can be seen by referring back to Figs. 217, 222, and 223. In the first figure, the flywheel has a triangular section with a solid web set at an angle so as to bring the flywheel nearer the engine; the inner surface is tapered to suit the clutch. In Fig. 222, the shape is entirely different and apparently much lighter. This is an eight-cylinder engine. Here the flywheel section as a whole has a short U-section, being externally a short section of a cylinder. The web, too, is perfectly straight at one end. The inside is cut out for the clutch, but with a very slight angle. The shape of the flywheel in Fig. 223 is somewhat similar to that of Fig. 217, but it is wider and not so thick. It shows a larger diameter, too. The exterior is plain and straight except at the front edge where the starting-ring gear teeth are cut into a raised portion of it. The web is straight and solid, close to one end, but not flush with it as in Fig. 222.

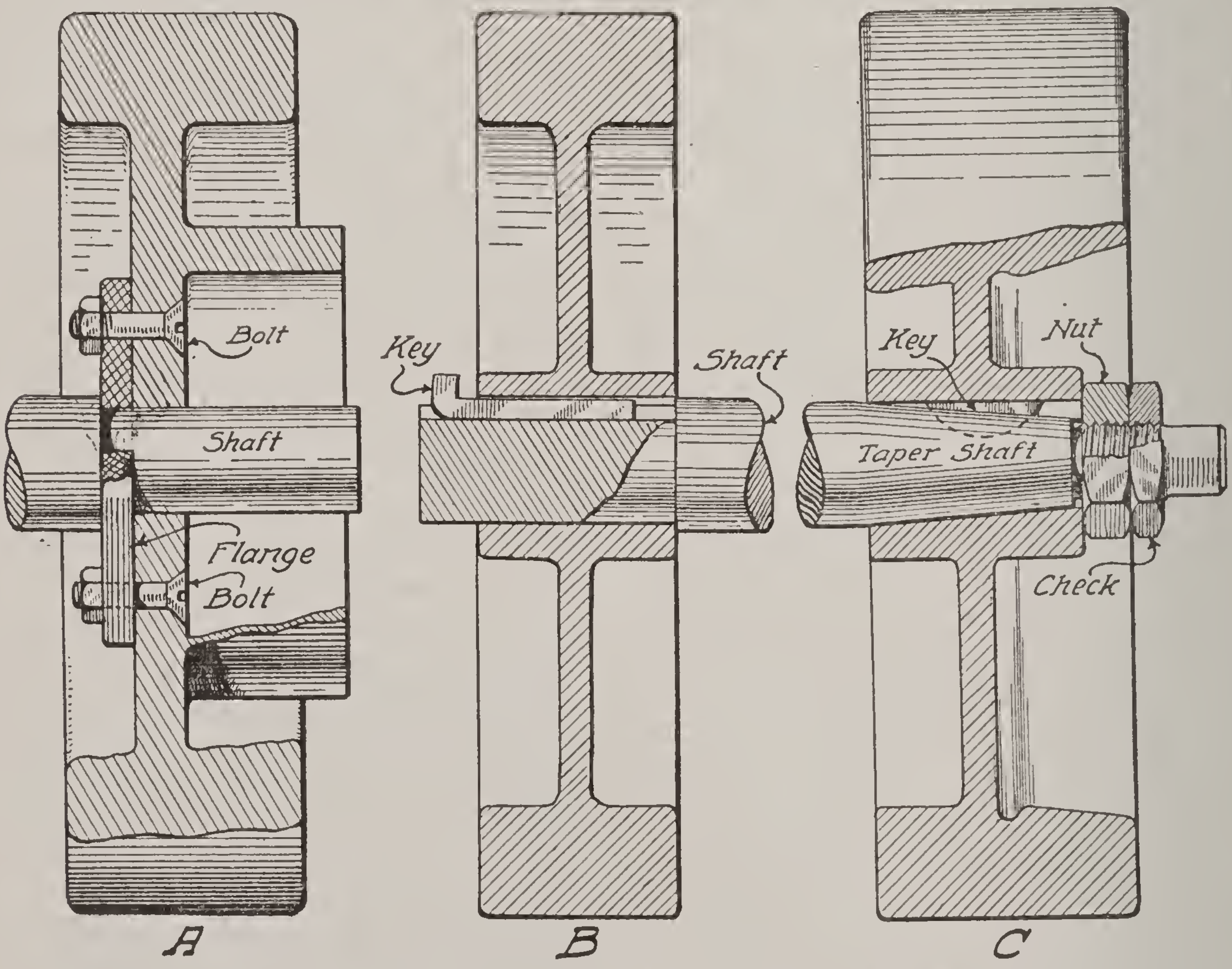


Fig. 245. Three Common Methods of Fastening Flywheel: *A*, Flange and Series of Bolts; *B*, Plain Key; *C*, Key, Taper and Nut
Courtesy of N. W. Henley Publishing Company, New York City

Methods of Fastening Flywheels. That part of the flywheel which is most interesting to the repair man is the method of fastening, or rather the inverse of this, the method of removal. There are three general methods of fastening flywheels to crankshafts, and these are shown in Fig. 245. They are the plain round end with a key, as shown at *B;* the tapered end with key, nut, and lock nut, as shown at *C;* and the method of bolting to a circular flange integral with the crankshaft, as indicated at *A*. The first is widely used for stationary gas and marine engines of very low price, but very little, if at all, on automobile engines. The second has been used, but is rapidly going out, as it is, like the first, a low-priced method which did not prove satisfactory. The third method is rapidly becoming universal.

In use, the flywheel flange on the crankshaft is generally five or six inches or a figure between these, in diameter, with six to ten bolts. In the form shown at *C*, Fig. 245, the flange is exterior to the flywheel, but in Figs. 217 and 223, the more general method of grooving the flywheel hub to receive the flange will be noted. In Fig. 245, the bolt shown has a countersunk head let into the flywheel surface; in general, the bolt head is either standard or else round and set into a countersink. In this case, it is slotted for a screwdriver. Also a single nut is shown, whereas a nut and lock nut, or, at least, nut and lock washer, are always used.

Flywheel Markings. As has been noted previously under Valves and Valve Timing, the surface or rim of the flywheel generally carries upon it marks to indicate to the repair man the timing of the motor. Some makers give only one or two marks for a single cylinder, reasoning, with some degree of correctness, that if the first cylinder is set right, the others must be pretty nearly so, and that more marks would only confuse. Others put on their flywheel all the marks for all the cylinders.

Summary of Engine-Group Treatment. In Parts I, II, and III, the entire engine group has been discussed in detail. The different sections have been handled according to present practice and methods of operation. It is easily possible that the near future may bring about the elimination of one or more of these groups or its combination with some other.

The engine, too, has been discussed in its present form only, although some attempts have been made here and there to indicate the trend of developments. He would be a very foolish man who, knowing the past history of the automobile engine, would say that it has now reached perfection and will always have its present form. On the contrary, there seems every reason to believe that hardly a single feature of our present-day engine, at least in its present form, will be found in the up-to-date engine of ten or twenty years from now. This constant change renders a work of this kind almost impossible of absolute up-to-dateness, for changes are actually made and put into use while the book is being printed. As far as possible, however, the work aims to discuss the modern developments and yet to give the repair man, in particular, the information he needs as he comes in contact with cars of all classes, ages, and conditions.

SUMMARY OF INSTRUCTIONS

VALVE SUB=GROUP

Valves

Q. For what purposes are valves used?

A. Valves are used (1) to admit the mixture created in the carburetor into the cylinders at the proper time in the stroke and in the proper quantity (called admission or inlet valves); and (2) to allow the burned gases to be exhausted from the cylinders at the proper time in the cycle (called exhaust valves). At all other times the valves remain tightly closed. The valves, closing upon a machined seat and opening and closing at precise times and in an exact manner, give a control over the operation of the engine which is not possible in any other way.

Q. How are these valves opened and closed?

A. By means of cams, or projections, upon a rotating shaft called the camshaft, these projections raising the valve off its seat, or opening it, at the proper time. When the projection allows the valve to come down onto its seat, or close, a strong spring comes into action, forcing it to do this in a positive manner.

Q. How is the camshaft operated?

A. By gears or chains from the crankshaft, these being designed and assembled carefully, so that the camshaft will revolve at precisely half the speed of the crankshaft.

Q. Why should the camshaft revolve at half the crankshaft speed?

A. Because the operation of opening and closing the valves comes on every other stroke only, and the camshaft really works twice as slowly as the crankshaft.

Q. What is the general form of a valve?

A. The usual form is called a poppet valve, and its section is that of a letter T, having a long slender stem at the top of which is a large flat head. The lower surface of this head is machined off to fit the seat in the cylinder, while the upper surface is rounded up to the center, where a slot for a screwdriver is provided.

Q. Are there other forms of valves?

A. The piston form of valve is little used, but the sliding-sleeve valve is used on all Knight type of engines and some others. In addition, a few motors have been built with rotating-disc valves. The piston valve is similar to the usual piston, having a reciprocating motion in a special round-valve chamber made for this purpose. In its movements up and down, it uncovers ports in the walls, thus giving the equivalent of the poppet-valve opening. The sliding sleeve is a hollow cylindrical member entirely surrounding the piston and reciprocating in the same manner. In its up-and-down motions, ports in it register with ports in the cylinder walls at the proper points in the cycle, thus corresponding to the opening of the poppet valve. The rotating-disc valve acts on the same plan but consists of a flat or a conical disc which is gear-driven from the crankshaft. It has a hole, or port, in it which registers with other ports in the cylinder at the correct time in the cycle. There are other forms of valve but none in wide use.

Q. What are the advantages of the poppet valve?

A. Its simplicity is its greatest asset. The poppet valve is the simplest and most easily understood form of all. In addition, it will withstand continuous operation at the highest temperatures.

Q. What are its disadvantages?

A. It affords a comparatively small opening, smallest at the beginning and ending of the suction stroke, where it should be largest; it has a noisy hammering action which makes for rapid wear, constant adjustment, and frequent renewal; the actual seat is so small and is exposed to such variations of temperature and other severe conditions that it tends to wear out and leak very rapidly, thus reducing the power and speed, rendering action uncertain and calling for frequent regrinding; finally, the necessity for ready accessibility for adjustment allows the driver, or operator, to alter the action with a consequent influence upon the output.

Q. Can any of the disadvantages be overcome?

A. The opening cannot be changed, but the noise can be reduced by enclosing the whole valve action in removable covers. The influence of hammering in the way of wear, need for adjustment, renewal, leakage, etc., can be minimized by the use of tungsten steel, which is harder and wears much more slowly. The use of this material also lessens power and speed losses, uncertain action, and frequency of regrinding.

Q. Is there any way in which the design can influence these?

A. Recent tendencies and experiments have shown that with an arrangement for positive, or mechanical, closing of the valve, springs can be made very small and weak, thus eliminating the cutting action of the usual stiff spring on the cams and reducing the hammering action and the noise.

Q. Have sleeve valves any springs?

A. No. They are operated by eccentrics from the eccentric shaft, which corresponds to the camshaft in a poppet-valve system. These are positive at all times, that is, the sleeves are always mechanically operated and thus are unvarying.

Q. What is the general shape of valve enclosures?

A. As simple as possible. Frequently, all the valve mechanism is enclosed by a single rectangular plate. More usually, it consists of two such plates. With a single plate, a pair of, or at most three, bolts are used to hold it in place; with two plates, these generally have two bolts each.

Valve Timing

Q. How is the valve timing arranged?

A. The inlet is allowed to open as soon after the upper dead center as the designer considers reasonable, and closes as far past the lower dead center as will allow the maximum charge to enter and still not let any of it blow out. It should be remembered that when the piston passes the lower center, it begins to rise and reduce the volume in the cylinder. Similarly as to the exhaust, it is allowed to open as much before the lower dead center as will insure full power, and is held open as long as possible, this sometimes overlapping the inlet opening and always passing the upper dead center.

Q. What is the average valve timing?

A. The timing of fifty-six American motors, including perhaps one hundred different models, averaged as follows: inlet opened from upper dead center to 21° beyond—average 10° 48′; inlet closed from 15° to 46° 22′ beyond lower dead center—average 35° 7′; exhaust opened from 31° to 57° 30′ ahead of lower dead center—average 50° 10′; exhaust closed from upper dead center to 21° beyond—average 9° 20′.

Q. How does the repair man know what the correct timing is?

A. Practically all makers give it in their instruction books and other literature as well as marking it upon the flywheel surface.

Cams

Q. How are the cams usually made?

A. On all the better motors, the cams are formed integral with the camshaft, which is machined, hardened, and ground as a unit. This keeps the timing always the same, which is sometimes not the case when cams are made separate and keyed and pinned in place. Moreover, the integral cams are more accurate, because the machines which have been developed for this purpose insure absolute accuracy.

Valve Guides

Q. What is the valve guide?

A. That member which forms the bearing as well as the support for the valve stem. Its importance can be judged from the fact that the guide holds the valve in line with its seat so that it seats itself accurately.

Q. How are valve guides usually made?

A. Generally, they are of cast iron and removable, being screwed into the cylinder from below. The diameter is made as small as possible and still give sufficient stiffness and strength; the length is made as great as possible, for the entire length of the valve guide is bearing surface for the valve stem.

Exhaust Manifold

Q. What is the influence of the exhaust manifold?

A. To remove the exhaust gases from all cylinders as quickly and as thoroughly as possible. If this is not done, the burned gases will retard the next outflow of gas, until finally the engine may be stopped because it is not receiving rich enough fuel. The best form of exhaust manifold is the one which does this work most quickly and most thoroughly.

Q. What is its general form?

A. A long cast-iron member of round or rectangular section, slightly larger at the outlet end, and bolted to the cylinder casting.

Q. How can this be improved?

A. Recent experiments have shown that an arrangement of shape and size can be effected which will bring about an ejector effect immediately back of each exhaust orifice. This will produce a slight suction upon each succeeding volume of burned gas, which will increase the efficiency of the exhaust and thereby improve the power of its motor.

Muffler

Q. What is the purpose of the muffler?

A. To reduce the pressure of the exhaust gases so that when emerging into the atmosphere they will do this without noise. As they emerge from the cylinders, the pressure is fairly high, and if they were allowed to pass immediately into the air, the noise would be deafening.

Q. How is this silencing accomplished?

A. By successive expansions, each of which reduces the pressure considerably. The gases come into a small central tube and are allowed to expand into another surrounding chamber of perhaps double the area, with consequent reduction of pressure. Then they are allowed to expand into another chamber, perhaps twice as large as this, with further reduction of pressure. This process is continued until practically all pressure is eliminated, so that the gases will emerge without noise.

COOLING SYSTEMS

Q. How are explosion motors cooled?

A. Mainly by the indirect method in which water surrounding the cylinders removes their heat and then is itself cooled in the radiator. The direct, or air-cooling, method is now used by but one maker, Franklin.

Q. What is the general cooling method?

A. There are two methods in general use, called the natural, or thermosiphon, and the pump systems. The former is so-called because the natural increase in temperature of the water is used to circulate it to the radiator and back. The latter is called a pump system, because a pump is used to force the water around.

Q. Are there other differences between the two?

A. In the thermosiphon system, the difference in pressure created by the increasing temperature is so slight that all bends must be made very easy and all pipes made very large, so the water will pass easily. Also the system as a whole must be short and compact with radiator close to motor, and with little difference in level between the highest and lowest points. The added weight of larger pipes and their appearance just about balance the simplicity and smaller number of parts.

Q. What general types of radiators are in use?

A. The cellular (which may have square, round, or hexagonal cells) and the tubular form with horizontal fins sweated on are the two forms generally used.

Q. How does the water circulate in these two forms?

A. In the cellular form the water is in very thin sheets between the cells, with a consequently high ratio of air space to water space. The water is forced to follow a zigzag path to add to the cooling effect. In the tubular form, the water flows from an upper to a lower tank through the vertical tubes, which are of relatively larger diameter as compared with the water space in the cellular form—$\frac{3}{8}$ against $\frac{1}{32}$.

Q. What is the usual form of pump?

A. Four forms of pumps are used for water circulation: the centrifugal, the gear, the plunger, and the vane. The first two are used about equally on the majority of American pleasure cars, the last two having but a few adherents.

Q. What is the latest move to improve water circulation?

A. The use of a thermostat to control the flow of the water according to its temperature. This device holds the water in the cylinders until a certain predetermined temperature is reached, when it opens and allows the water to flow through the radiator and be cooled. By setting this so that this predetermined temperature is high, but not so high as to be dangerously close to the boiling point, the efficiency of the engine is increased, for a hot engine works better than a cold one and gives more power.

Q. What is the purpose of the fan?

A. To increase the efficiency of the radiator by drawing more air through it and thus cooling the water more.

Q. How is the fan generally driven?

A. The belt drive, using a flat or V-type belt is general because of its simplicity, but a few better cars have gear or chain drive; the latter method has increased in recent years particularly with the V-type motors, for in those it has been found easy to drive the fan from a shaft in the immediate vicinity.

Questions for Home Study

1. Describe in detail the timing of the Knight motor.
2. Tell how to regulate and check up the valve action from the flywheel marking.
3. How are silent-chain camshaft drives adjusted? How are gears?
4. How is the valve-stem clearance adjusted?

LUBRICATION SYSTEMS

Q. What is meant when lubrication is referred to?

A. In general, the lubrication of the engine, because that is so much more important than the lubrication of any other part or group of parts. If the engine is run without lubricant, even for a very short time, it is ruined. On the other hand, many of the car parts can be run without lubricant for days and days, yet no damage will result.

Q. What are the most used systems for the internal oiling of the engine?

A. The most used systems are: the splash, the pressure, and a combination of the two, known as the splash-pressure, or constant-level, system. The first is simple, oil being provided in troughs into which the connecting rods dip, thus spreading the oil all over the interior of the motor and lubricating everything. The pressure system forces oil under pressure to all the important bearings and surfaces by means of interior-drilled oil leads or special pipes. It requires a pump, driven from some engine shaft, one or more strainers (for the oil is used over and over), the special drilling or piping, a gage on the dash to tell the driver how the system is working, and in some cases an adjustable pressure valve. The splash-pressure form has the oil leads to the important points only. Then the excess runs down into the crankcase and fills troughs into which the connecting rods dip. In some cases, these troughs are filled by direct individual leads off of the main oil pipe. Then when the rods dip into the oil, all benefits of the splash system are obtained. The fact that the pump maintains a constant level of oil in the troughs has led to calling this the constant-level system.

Q. What pressure is used in the pressure system?

A. Prior to the introduction of V-type and high-speed motors, a few pounds less than 5 was considered sufficient. Now, many motors have a system which works under 40, 50, 60, and even 70 pounds pressure. The oil leads are smaller, but the amount of lubricant which the bearing receives is much greater than previously.

Q. What is the external lubrication of the motor?

A. The lubrication of the accessories, such as magneto, water pump, starting motor, generator, air pump, fan, etc. Practically all these have oil holes, oil cups, or grease cups. The last named must have a special heavy grease or pure mutton or beef tallow, as a thick lubricant is needed to resist the passage of the water and not wash away. Otherwise the external lubrication is fairly simple and requires little attention.

Q. What are the most used types of oil pumps?

A. Like the water pump, all forms are used but the most popular are the cam-operated plunger, the gear, and the plunger.

Q. How are these driven?

A. By gear from any convenient shaft, as camshaft, crankshaft, water-pump shaft, magneto shaft, etc. When the pump is enclosed in the crankcase, it is almost invariably driven from one of the camshafts.

Q. How are other parts of the car lubricated?

A. Aside from clutch, transmission, rear axle, and wheels, practically all parts are lubricated by means of grease or oil cups or oil holes. The latter are rapidly being eliminated for the sake of cleanliness.

Q. What are possible future developments in oiling?

A. At present, there are two tendencies noticeable, one being the extension of forced lubrication to many parts outside the engine.

In the case of the Fergus car, the springs are enclosed in leather boots and lubricant supplied from the engine oil pump. Similarly, clutch and transmission are oiled from the engine pressure system. The 1917 Marmon car is claimed to have but four or five lubricant points outside of the engine system. Another maker has adopted the leather-enclosed and lubricated springs. All these signs point toward less lubrication for the driver and owner to do, more points being included in the engine system. The other noticeable point mentioned has been partially covered; it is the reduction in number of points requiring individual attention, by other means than extending the engine pressure system to them.

Q. How should graphite be used?

A. Graphite should be used very sparingly, for a little of it goes a long way. It is not like grease which is used up very quickly, but is more or less indestructible. When a combination of graphite and grease is used, it will be found to last twice as long at any given point as the same quality of grease alone. Graphite in its very finest form, when introduced into the engine system, is beneficial as it seems to put a kind of polish, or surface finish, on the cylinders, which resists wear. After this has been put on, less lubricant, by at least 20 per cent, can be used in the engine. It should, however, be used in very small quantities, two tablespoonfuls to a gallon of oil being sufficient

Q. What is its big advantage?

A. In addition to the fact that it seems to fill up the pores and surface scratches of the parts on which it is used so as to give them a fine finish, graphite has the advantage of resisting the very highest temperatures very well, so that its use constitutes a safeguard against immediate injury in case of neglect.

Q. What are oilless bearings?

A. There are two forms of oilless bearings, one of hard wood which has been impregnated with lubricant by boiling in oil, or some similar impregnation process, and the other is a bronze and graphite combination, in which about half the bearing surface consists of plugs or strips of pure graphite. These graphite surfaces supply the lubricant for the entire bearing, which never needs additional lubricant, so it is claimed.

Questions for Home Study

1. Describe the lubricating system of the Pierce-Arrow car.

2. How is the Cadillac eight motor oiled? Give details.

3. What is the usual method of changing the amount of oil pumped, in a pressure system?

4. Select some method of driving the oil pump, which seems simple to you, and describe it, telling why you selected it.

5. How would you lubricate spring leaves, with what and how often? fan bearings? front wheel bearings? magneto shaft? differential?

6. How do you select a good engine oil?

FLYWHEEL GROUP

Q. How does a light flywheel affect an engine?

A. The engine will be easy enough to start and stop, but very touchy on changing speeds—too quick a change will kill it. Moreover, it will not run very slowly.

Q. How do present flywheel sizes compare with those of former years?

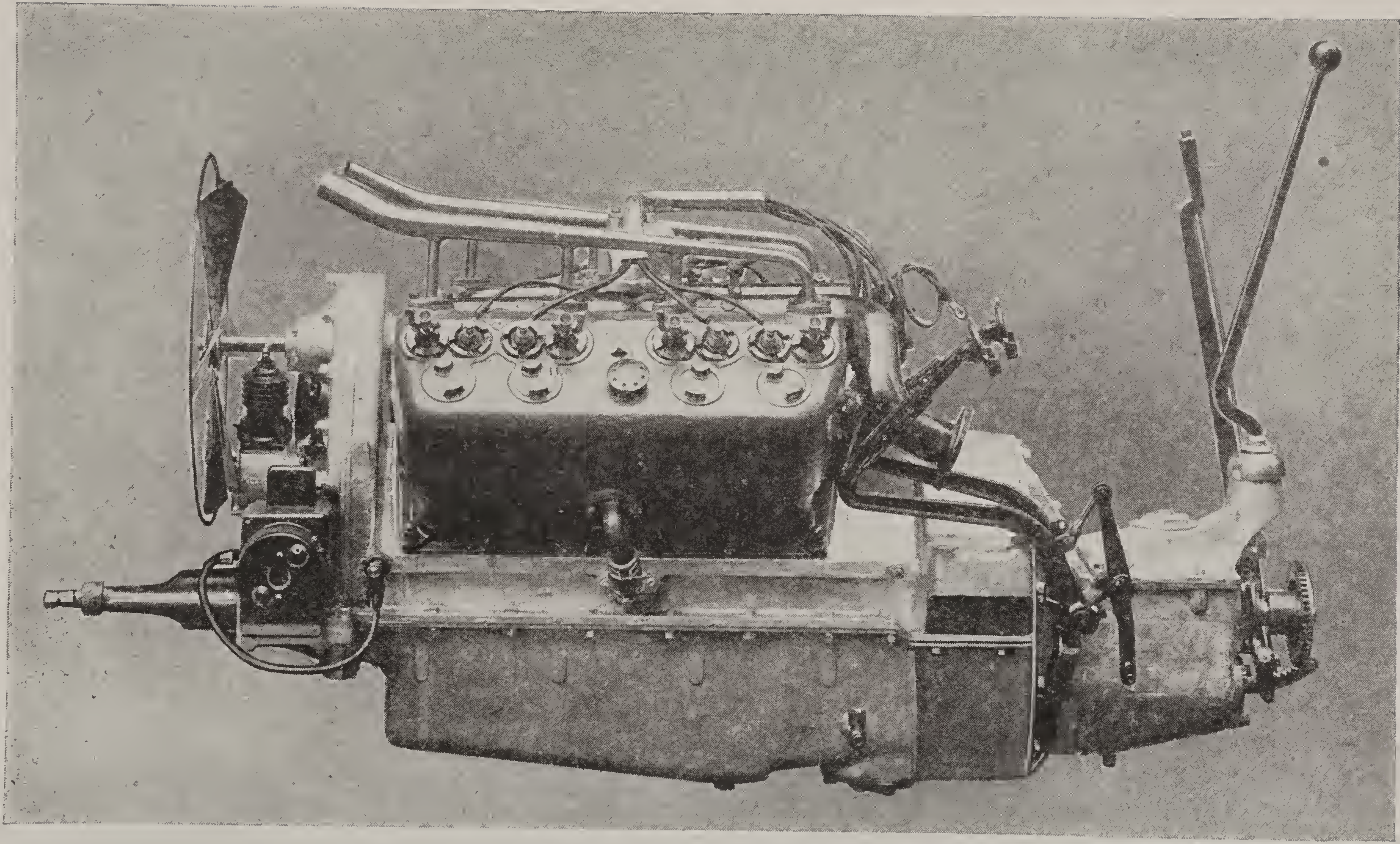
A. Present flywheels are larger in diameter but narrower and lighter in weight. The increase of diameter made by the elimination of subframes allowed cutting down the width and weight because the flywheel effect is equal to its mass times its radius, so that by increasing the radius the mass can be reduced.

Q. What are the usual methods of flywheel fastening?

A. The flange forged on the crankshaft and through bolts is almost universal. A few motors are still made with a round crankshaft end and a large key; or with a tapered shaft end, and a key, a nut, and a lock nut. The latter form is used when the crankcase is of the barrel type with removable end plates and is so made as to allow removal of the crankcase end plate at the rear. In some few cases the flywheel is made this way so as to allow putting on or taking off a ball bearing at the rear end of the crankshaft.

Q. What are the markings on the flywheel rim?

A. The timing is now generally marked on the surface of the flywheel to guide the owner or repair man in making adjustments or in assembling the engine correctly. The adjustments vary; some makers give the complete timing for a single cylinder, others give a few points for all, and still others give all the points for all the cylinders. The latter is the best way.



SIDE VIEW OF PEERLESS EIGHT-CYLINDER MOTOR
Courtesy of The Peerless Motor Car Company, Cleveland, Ohio

GASOLINE AUTOMOBILES

PART IV

CLUTCH GROUP

TYPES OF CLUTCHES

Classification. Principal among the indispensable parts intervening between engine and road wheels, and one which may be a source of great joy or correspondingly great wrath, according to whether it be well or poorly designed and fitted, is the clutch. There are six forms into which clutches may be divided, although not all of them are in general use in the automobile. Only the first four are widely used on automobiles. These different forms are:

(1) Cone clutches
(2) Contracting-band, or drum, clutches
(3) Expanding-band, ring, clutches
(4) Disc and friction clutches
(5) Hydraulic, or fluid, clutches
(6) Magnetic, or electric, clutches

The necessity for a clutch lies in the fact that the best results are obtained in an automobile engine when run at constant speed. In as much as the speed of the car cannot, from the nature of its use, be constant, it requires some form of speed variator. This is the usual gear box, or transmission, but, in addition, there is the necessity of disconnecting it from the motor upon starting, since the engine cannot start under a load. There is also the necessity for disconnecting the two when it is desired to change from one speed to another either by way of an increase or a decrease. So, also, when one wishes to stop the car, there must be some form of disconnection. There are, then, three real and weighty reasons for having a clutch.

Requirements Applying to All Clutches. In a serviceable clutch there are two general requirements which are applicable to all forms. These are gradual engagement and large contact surfaces, although the latter requirement may be made to lose much of its force by making the surfaces very efficient. In the cone clutch, gradual engaging qualities are secured by placing a series of flat springs under the leather or clutch lining. By means of these springs, acting against the main clutch spring, the clutch does not grab, since the large spring must have time in which to overcome the numerous small springs. In this way, the engagement is gradual and the progress of the car is easy as well as continuous.

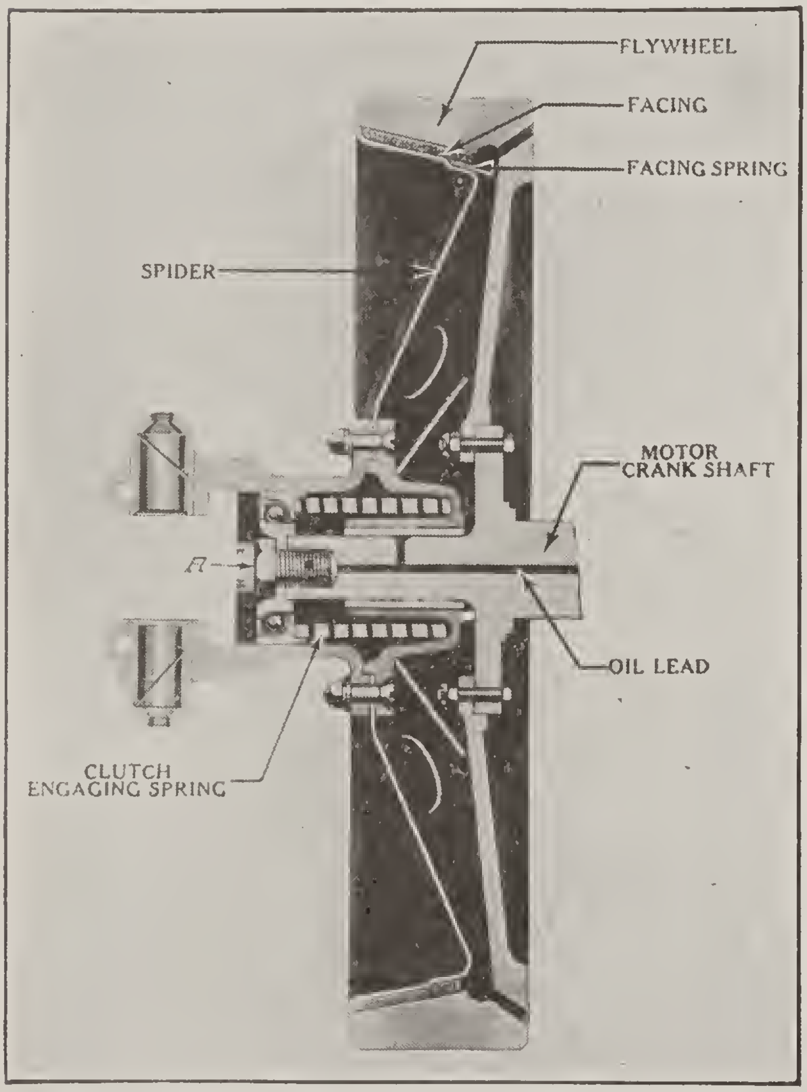


Fig. 246. Section through Studebaker Direct Cone Clutch
Courtesy of Studebaker Corporation, Detroit, Michigan

The specific necessity in a cone clutch, whether it be direct or inverted, is a twofold one—sufficient friction surface and proper angularity. The latter, in a way, affects the former, as will be discussed more in detail later. The angularity varies in practice from 8 to 18 degrees.

Cone Clutch. The cone clutch consists of two members, one fixed on the flywheel or other rotating part of the engine and the other fixed to the transmission shaft. The latter usually slides upon the shaft so as to allow engagement and disengagement. A spring holds the two together or apart, according to the type of clutch used. When the smaller-diameter member is spoken of, it is usually called the male member, while the part of larger size is spoken of as the female member.

The cone type is made in two different varieties: one in which the male member enters the female naturally at the open end is called the direct cone type; in the other, the male member is set within the structure of the female and is pressed outward toward the open end to engage it. This is called the inverted, or sometimes the reversed, cone clutch.

A great disadvantage of the inverted form is that the spring must be carried between the two cones, which means that it is inside where it cannot be reached for adjustment. This form causes trouble in assembling because the male cone must be put in place with the spring between it and the flywheel before the female can be set into its place and bolted up. These two big sources of trouble have caused designers to turn to the direct type more freely, as it lends itself readily to an external adjustment. If the spring is outside, it is easily put into place and as easily taken out.

An excellent example of the direct cone clutch is seen in Fig. 246, which shows the Studebaker clutch in section. The noticeable point about this clutch is its simplicity. It will be noted that the spring is entirely enclosed, so that when it needs adjusting the repair man must open the universal joint and operate the bolt *A* which regulates the tension of the spring.

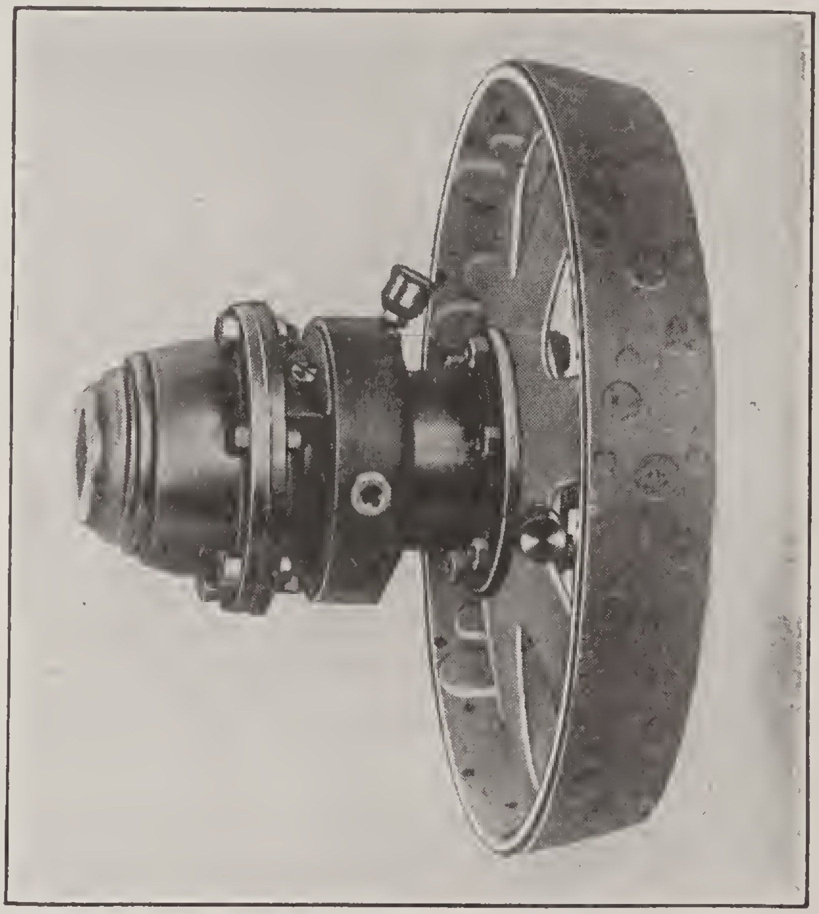


Fig. 247. Direct Cone Clutch with Cork Inserts

Another good example of the simplicity of the cone clutch is seen in Fig. 247, which is an aluminum member with bosses cast for cork inserts. Between the inserts may be seen the flat heads of the copper rivets which hold the clutch facing in place. Obviously, this has the same disadvantage of internal, and thus inaccessible, spring.

In the cone type of clutch, shown in Fig. 248, the inaccessible spring is avoided. In addition, a number of small springs are used in place of one very large and very stiff one. The ease of adjustment and the greater ease in handling the springs make this clutch a much better design for average use from the repair man's point of view.

An example of the inverted-cone type is shown in Fig. 249, which shows the clutch on the four-cylinder Stearns-Knight. This type has an odd number of small springs equally spaced around the clutch, but these cannot be adjusted from the outside.

Contracting-Band Clutch. A short consideration of the band style of clutch shows that this does not differ radically from the ordinary band brake, either in construction, application, or actual working. The difference in the two lies in the fact that the band, as a clutch, is designed to transmit power with as little loss as possible, while the band as a brake is designed to absorb the forward energy of a moving vehicle in the shortest possible space of time, i.e., to waste as much power as possible.

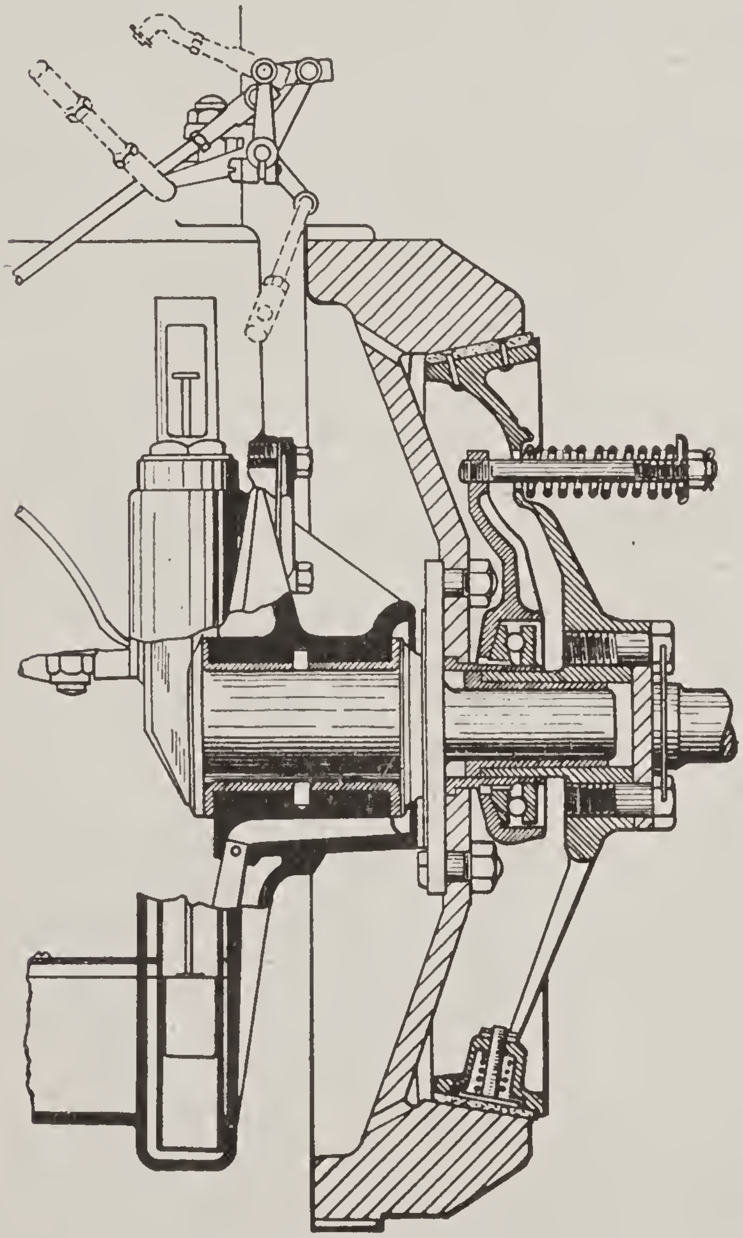


Fig. 248. Direct Cone Clutch with Small Springs and External Adjustment
Courtesy of Willys-Overland Company, Toledo, Ohio

Fig. 250 shows a typical contracting-band clutch. It will be noted that this clutch has the two parts, or sections, of the band united at the bottom and two operating levers pivoted at the top, where a single conical-shaped cam moves both outward and tightens the bands on the drum.

The usual place in which the band clutch is found is in connection with a planetary transmission. There the band is always used, and there it reaches its simplest form, that of the plain band wrapped around the drum. One end is fixed and the other attached to the braking, or more correctly, the clutching, lever. A plain pull on this effects the clutching action. A more modern and more efficient form has one end of the band attached to one extremity of the clutching lever, while the other end of the band is fastened to the middle of this lever. The clutching pull comes upon the upper extremity of the lever. Then the band acts to aid in clutching itself, i.e., a scissors action is obtained, and the required pull is lessened.

This construction can be seen quite plainly in Fig. 287, which shows the planetary transmission and bands used on Ford cars. In this, the low- and reverse-speed bands are shown in full. This is of particular interest as Mr. Ford is now the only American maker using the planetary form of transmission, all other makers, even of very low-priced machines—some below the Ford price—having gone to the selective sliding-gear form.

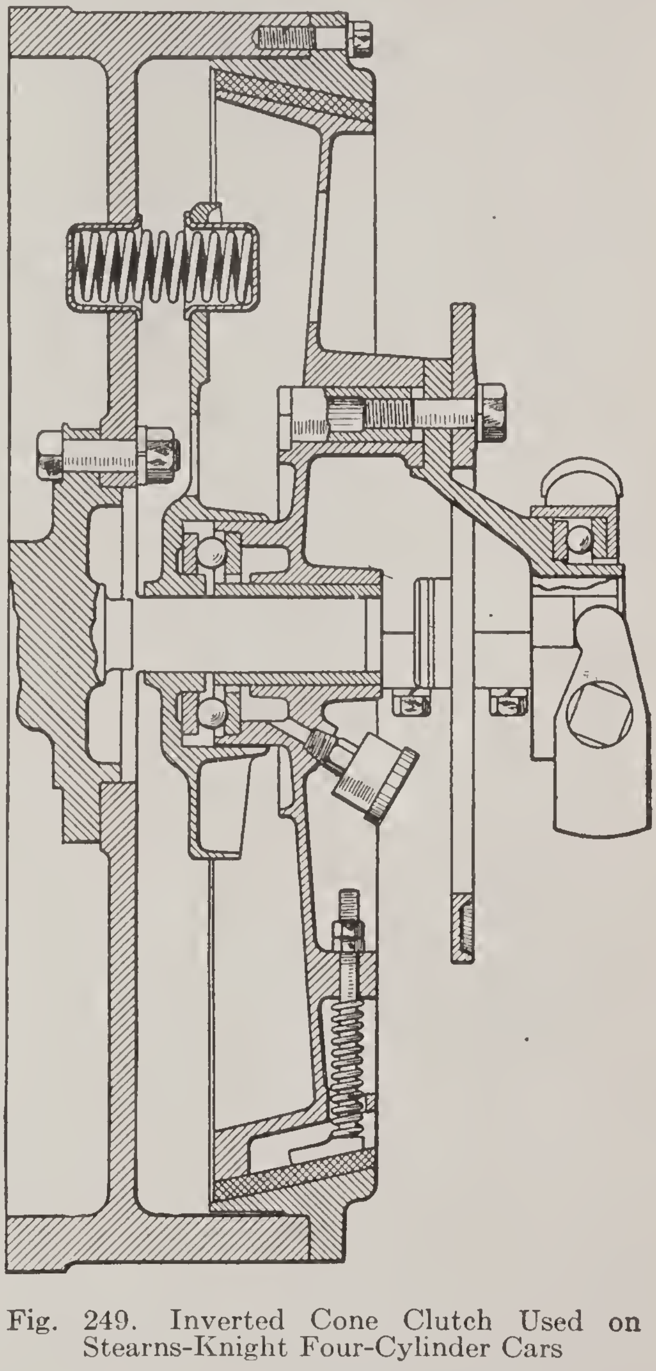


Fig. 249. Inverted Cone Clutch Used on Stearns-Knight Four-Cylinder Cars
Courtesy of F. B. Stearns Company, Cleveland, Ohio

Expanding-Band, or Ring, Clutch. The expanding-band clutch finds favor among few. Like the contracting band, which is very similar to the band form of brake, the expanding band is much like the expanding type of brake, except that the clutch is used to form the connection between two rotating parts. Viewed from the standpoint of pure engineering, the expanding band is little different from the cone type of clutch, granting that the angularity of the operating cam is the same as that of the cone.

Much depends upon how the band is expanded. This expansion is usually accomplished by means of screws, which may be either right-handed or left-handed or both.

Another form is expanded by a right-and-left screw operated by a lever. The lever, in turn, is moved by a pair of sliding collars on the main-clutch shaft, the clutch foot pedal moving these forward.

Disc Clutch. With its advent in 1904, the multiple-disc clutch has steadily grown in popularity, until today it is looked upon as the most satisfactory solution of the difficult clutch problem. Designers who have once adopted it, seldom, if ever, go back to another form, while of the new cars coming out from time to time nearly three-fourths are equipped with some form of disc clutch.

Popularity Compared with Other Forms. Statistics for 1914 showed that the disc form of clutch was easily the most popular type. Of 230 different chassis for 1914, 119 were equipped with disc clutches, 97 with the cone, 9 with a contracting-band type, and but 5 with an expanding-band form. The relative figures for 1916 were about 94 disc, 81 cone, no contracting band, no expanding band, and 1 electric. This would give the first-named approximately 54 per cent of the total.

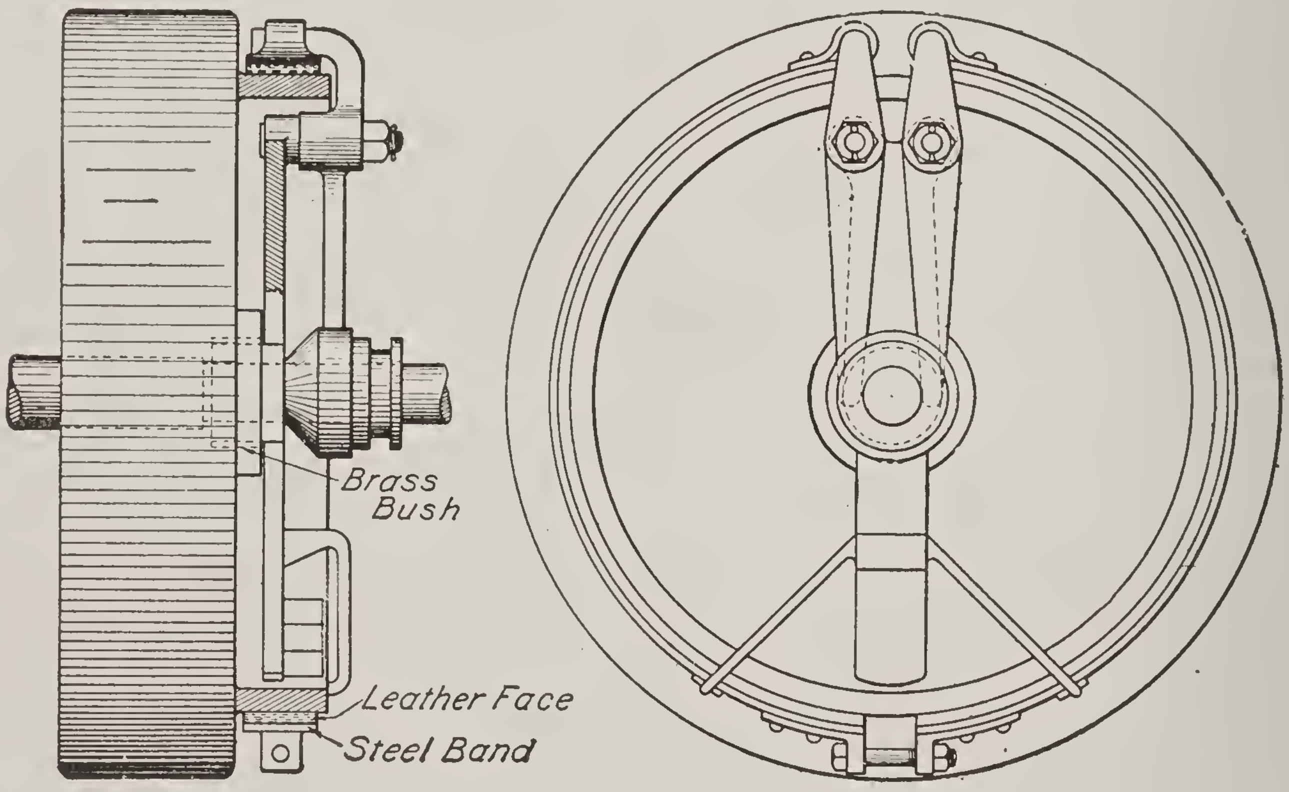


Fig. 250. Typical Contracting-Band Clutch

Two Forms of Same Make. Reference to the types of clutch brings to mind the relative advantages of the two leaders, the cone and the disc. These are presented in a very striking manner in Figs. 251 and 252, which show the cone and disc clutches used interchangeably by the Warner Gear Company, Toledo. These clutches are designed to be interchangeable, consequently the general layout is the same. It will be noted that the cone is somewhat simpler than the disc, as it has fewer parts which take up room. The design is such that the internal spring of the cone can be adjusted from the outside as can the outside spring of the disc. An interesting point in this connection is that the transmissions also are interchangeable, although the type, Fig. 252, with roller bearings is intended for a moderately heavy passenger car, while that in Fig. 251 is for lighter work.

Simple Types. The simple types differ in number and shape of discs, method of clutching, material, and lubrication; but in principle all are alike. This clutch is one in which the flat surfaces properly pressed together will transmit more power with less trouble than any other form. By multiplying the number of surfaces and making them infinitely thin, the power transmitted may be increased indefinitely. That this is not idle fancy is shown by a number of very successful installations of 1000 horsepower and over in marine service.

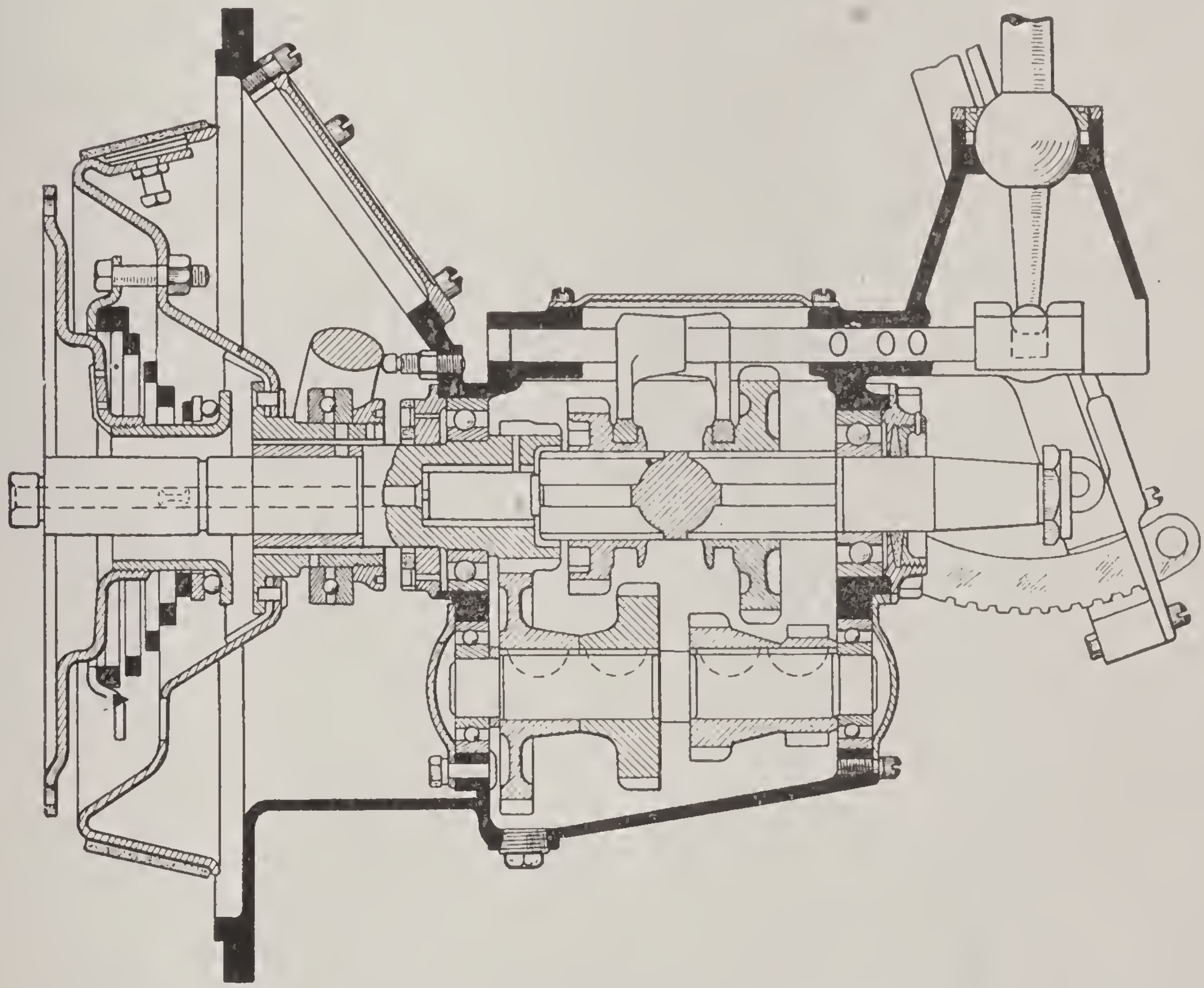


Fig. 251. Typical Three-Speed Gearset with Cone Clutch for Unit Power Plant
Courtesy of Warner Gear Company, Toledo, Ohio

The minimum number of plates in use is said to be three, but very often the construction of a three-plate clutch is such that one or two surfaces of other parts are utilized, making it a two- or even one-plate clutch in reality. In the Warner clutch, shown in Fig. 252, there are really but two clutching surfaces, the face of the inner plate against the flywheel and the outer face against the engaging disc. Both plates are faced with suitable friction surface but it really is a one-disc clutch.

Multiple-Disc Clutches. The modern tendency in disc clutches, however, is away from those of few plates requiring a very high spring pressure—since the friction area is necessarily limited—toward the multiple-disc variety, in which a very large area is obtained. The large area needs a very light spring pressure, and consequently it is easier to engage and disengage the clutch. For this reason, the multiple disc is becoming more popular with owners and drivers than the variety requiring the extra-heavy effort. The construction of the three-plate disc clutch does not differ radically from one maker to another. Three fingers are used to clutch and declutch generally, the amount of movement being adjustable. A single spring of large diameter and large-size wire is generally used, and sheet steel is used for one-half the clutch plates. Between the three-plate and multiple-disc are many gradations.

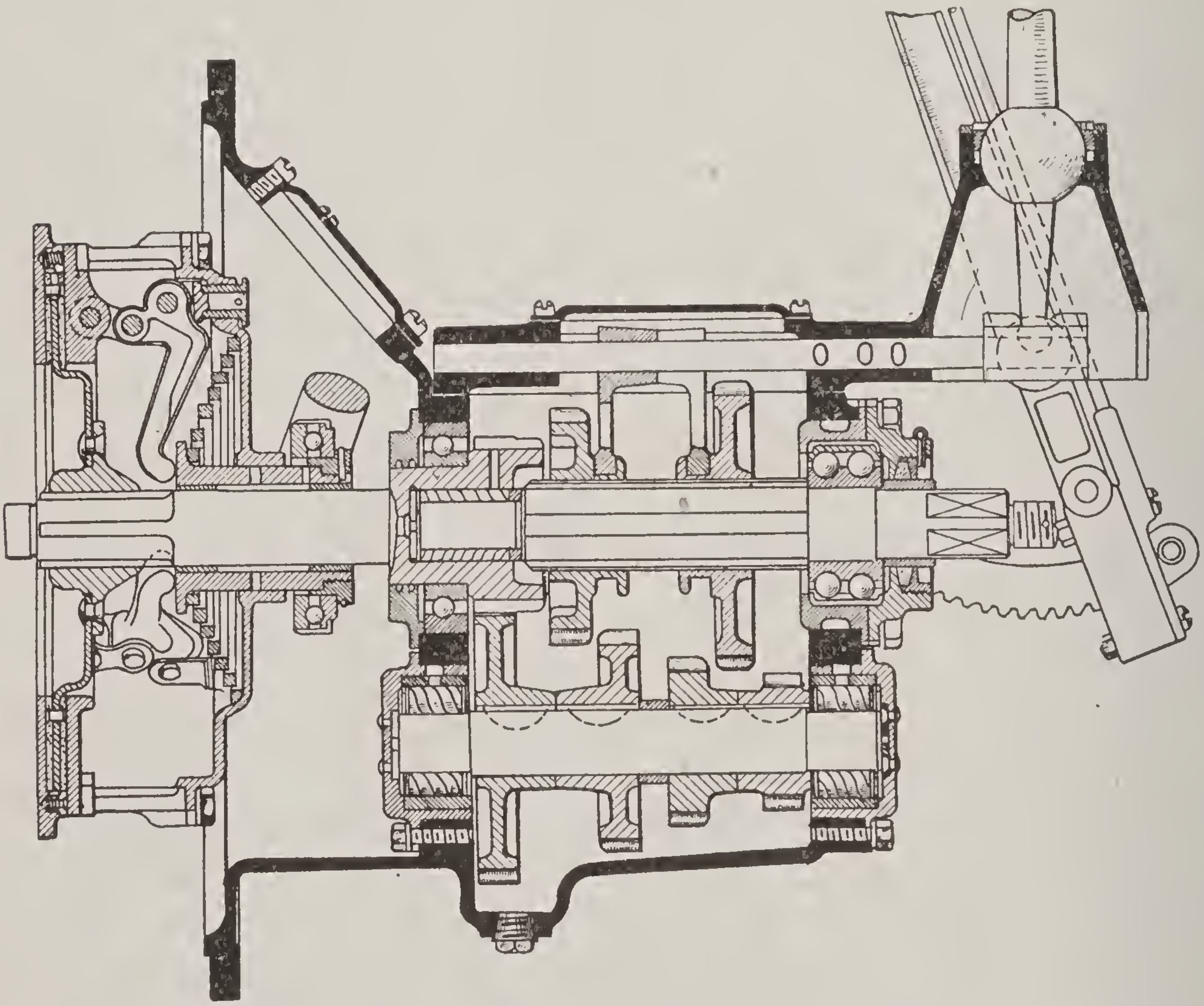


Fig. 252. Typical Three-Speed Warner Gear Box Shown in Fig. 251, but with Disc Clutch

In the true multiple-plate clutch, there are three general varieties met with in practice: the metal-to-metal with straight faces; the metal-to-metal with angular or other shaped faces designed to increase the holding power; and the straight-face kind in which metal does not contact with metal, one member either being lined with a removable lining or fitted with cork inserts.

Metal-to-Metal Dry-Disc Type. The metal-to-metal method has the additional advantage of having the central part within which the clutch is housed very small in diameter, so that the portion of the flywheel between the rim and the clutch housing may be made in the form of fan spokes that convert it into a fan which serves to cool the motor better.

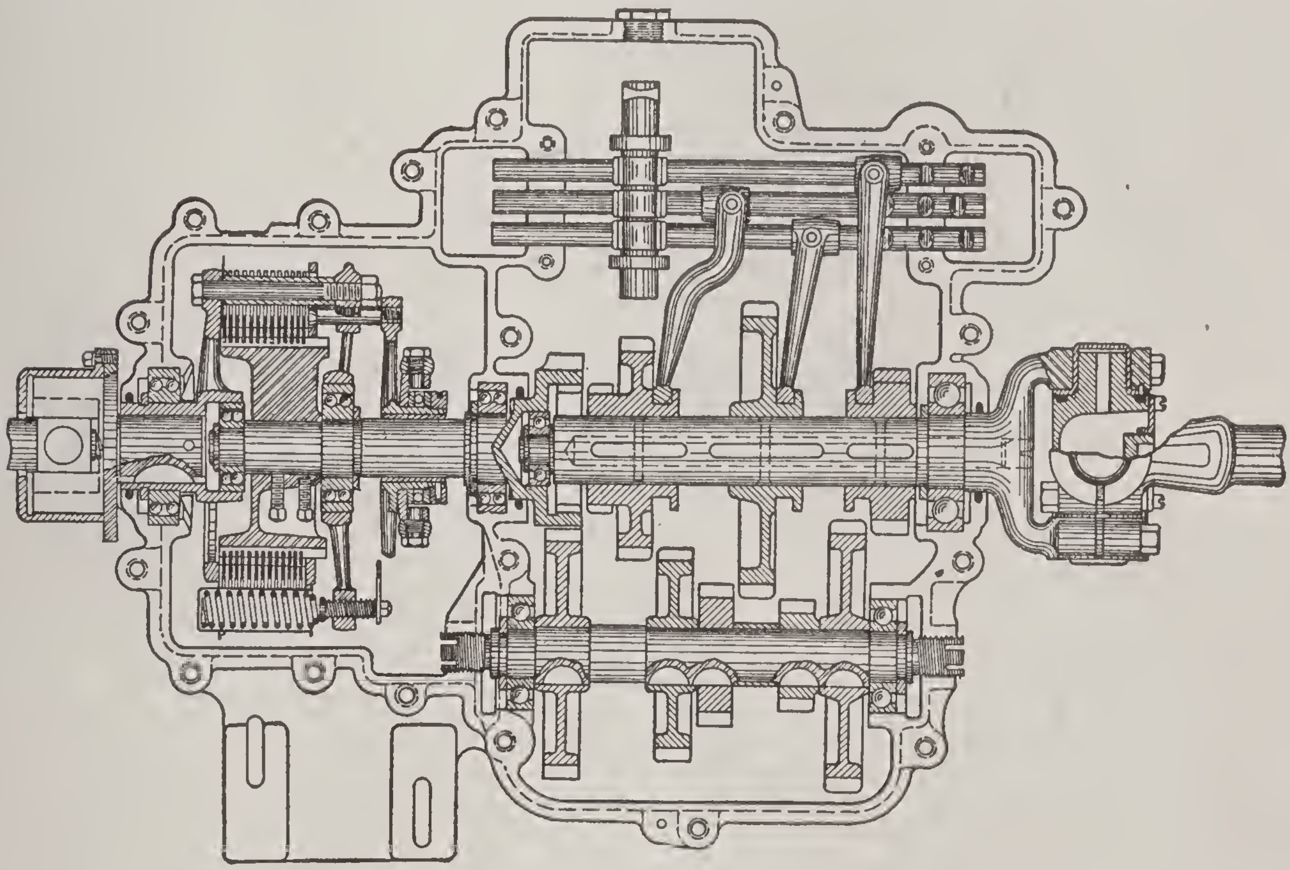


Fig. 253. Multiple-Disc Clutch and Transmission of Winton Cars
Courtesy of Winton Motor Car Company, Cleveland, Ohio

As the various examples of disc clutch shown would indicate, the designer has had his choice between a few large discs and a large number of small ones. If he chose the former, the clutch could be housed within the flywheel, but that would make it inaccessible. If he chose the latter, the clutch could not be kept within the flywheel length. A separate clutch housing would be a necessity, but the clutch could be made accessible and flywheel fan blades could be used.

Another example of the plain metal-to-metal disc clutch is shown in Fig. 253. In this case also the clutch is not housed in the flywheel, as in most of the preceding examples of this form of clutch, but in the forward end of the transmission case, that is, instead of motor and clutch forming a unit, the clutch is a unit with the transmission. It is claimed that this position makes it more accessible, since it brings the clutch directly under the floor boards of the driver's compartment where it can be lubricated better. The lubrication is effected through communication with the gear part of the case, which is always filled with lubricant.

In the figure it will be noted that there are 13 driven discs, with keyways, which hold them to the driven drum. Note that the drum is held to its shaft by means of a pair of large set screws. The clutching springs are of small diameter and size, spaced equally around the periphery of the discs; each disc is enclosed in a small and thin metal casing. Attention is called also to the universal joint shown. This joint forms the rear end of the driving connection with the flywheel, which will be referred to later. These discs are flat-stamped out of sheet steel with the proper keyways for internal or external holdings.

Use of Facings. The more modern disc clutch has two sets of sheet metal discs, one of which is faced on one or both sides with a special material. Without a single exception, all the disc clutches shown have had plain discs against plain discs. This makes a simple and fairly inexpensive construction, but one that is not very efficient. The most recent tests have shown that metal against metal gives a coefficient of friction of but .15, which is reduced to .07 when the surfaces become oily or greasy. With one of these contacting faces lined with leather, the coefficient rises to .23 when dry and to .15 when oiled. Again if fiber is used for the facing, the coefficient becomes, respectively, .27 and .10, while with cork or with cork and leather, it becomes, respectively, .35 and .32. Here is a very apparent reason for (1) facing the clutch discs, and (2) running them dry.

By going over these figures, it will be noted that discs with almost any form of facing will show an increase in efficiency over the same discs without facing, varying from 60 up to almost 300 per cent. Again, any form of disc clutch, faced or otherwise, will show a much higher coefficient when dry than when oiled and thus a greater efficiency. These two facts point out the obvious reasons for the modern tendency toward the multiple-disc clutch, faced and running dry.

To present an example of the faced type, Fig. 254 shows the multiple-disc clutch of the eight-cylinder V-type Cadillac. In this illustration the eight driving discs can be seen with the facing on each side of each one. This facing is of wire-mesh asbestos, and between each pair of discs comes a plain driven disc, so that it has a facing of the asbestos against each side of the metal which it grips. The keys holding the inner discs to the shaft can be seen on the end of the housing, while the slots into which the keys project can be seen on the discs. By examining the group closely, the driven plain discs can be seen between each pair of the drivers. The method of driving these discs through a multiplicity of keys and grooves is unusual, but it is a good example of Cadillac thoroughness. Fig. 254 also shows the pedals and the exterior of the clutch case where it bolts up to the engine. This indicates how a unit power plant simplifies the control group and eliminates parts.

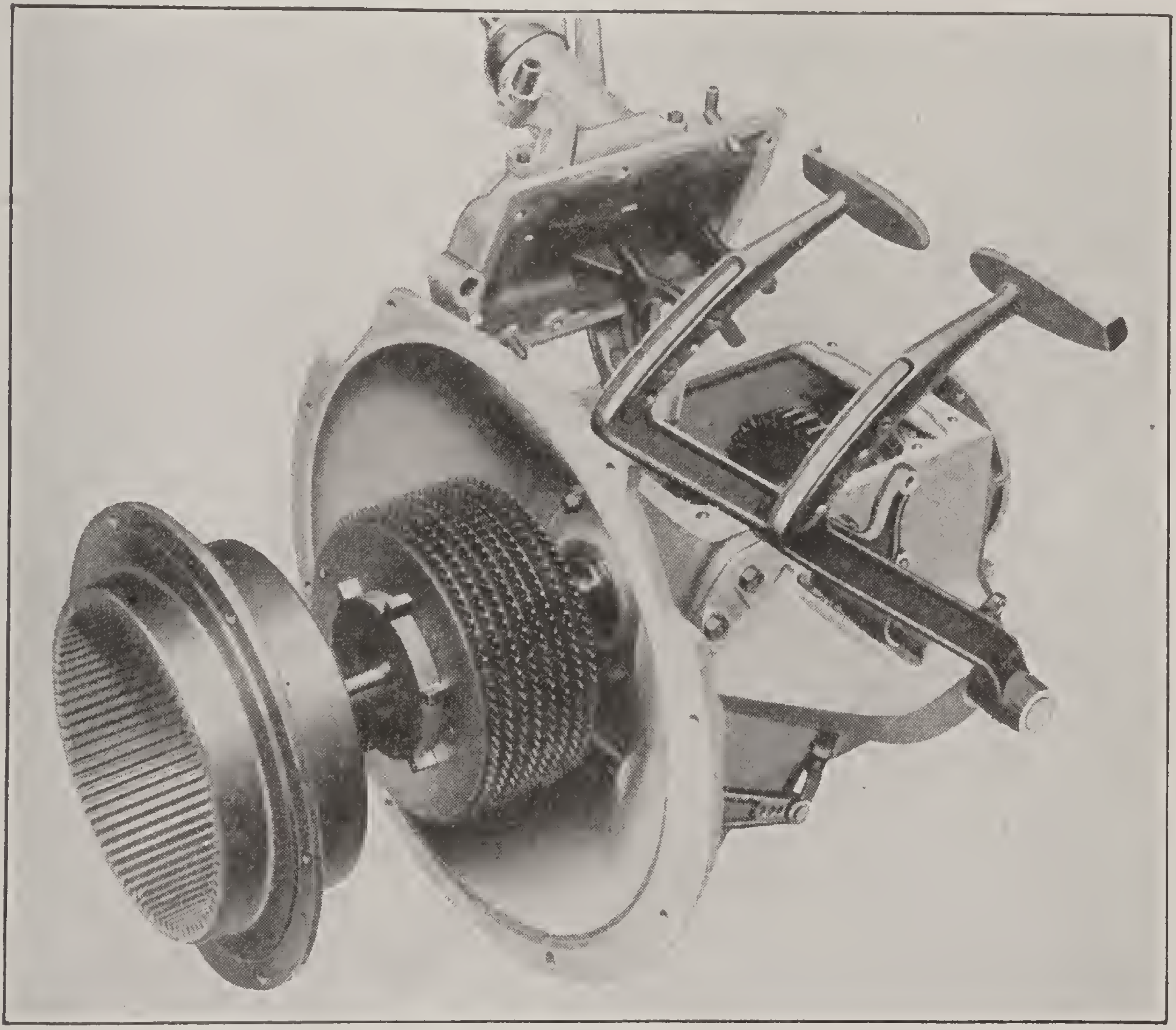


Fig. 254. 1917 Cadillac Clutch and Transmission, Showing New Clutch Drive
Courtesy of Cadillac Motor Car Company, Detroit, Michigan

Floating Discs a Novelty. The clutch on Locomobile cars, shown in section in Fig. 255, is very much like the Cadillac just shown, except for the novel feature that the fabric facings are not attached either to the driving or to the driven discs but float between them. This fabric, usually a woven asbestos material with a central core of interwoven metal wires, instead of being attached to both sides of every other disc or to one side of every disc, is not attached at all. The rings for the fabric discs are made up in the form of annular rings. They have the same inner diameter as the inside of the driving discs and the same outside size as the driven discs; consequently, assembling one of these clutches is simply a question of piling first a driven disc, then a fabric, then a driving disc, and so on.

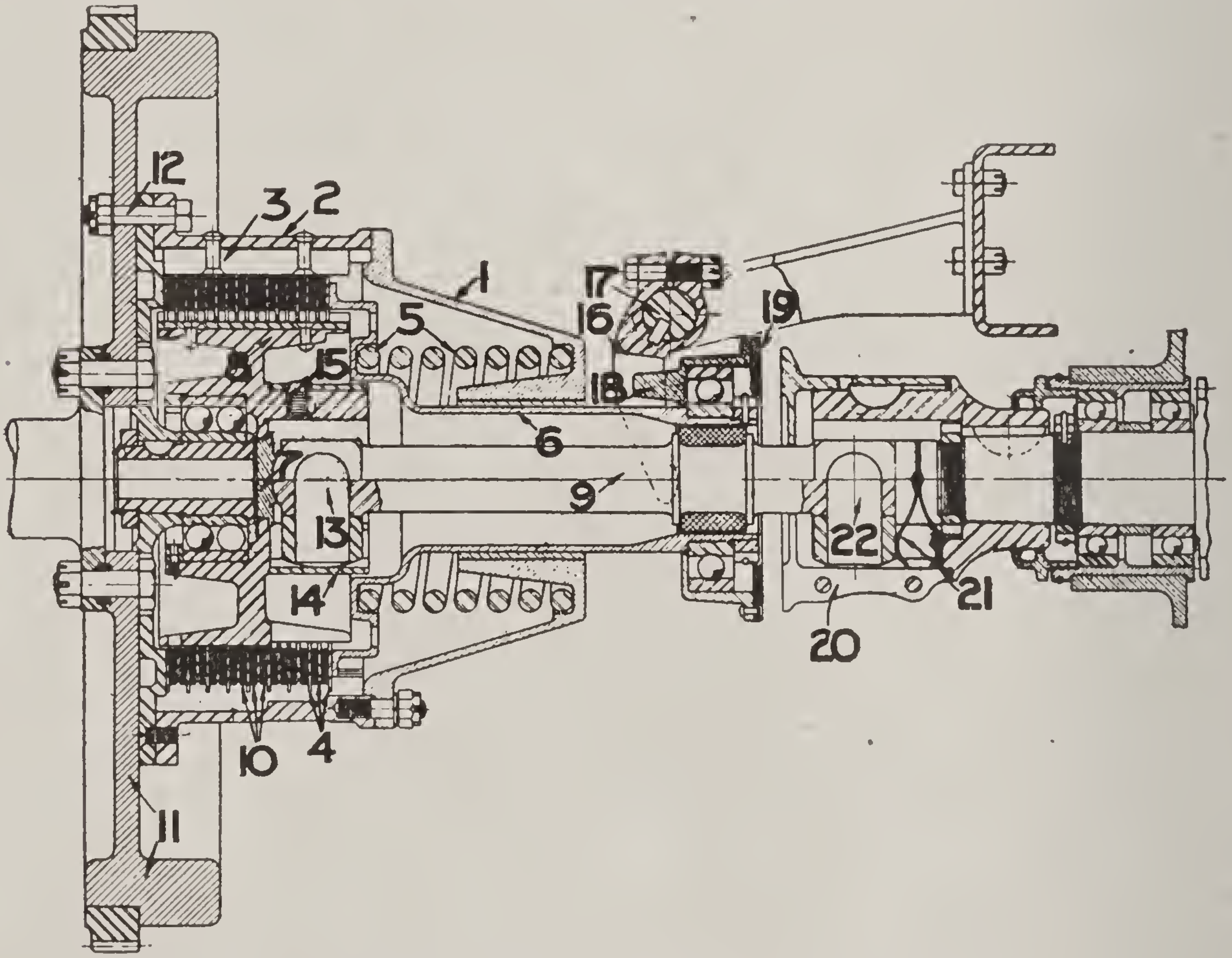


Fig. 255. Floating Dry-Disc Clutch Used on Locomobile Cars

The fact that the fabric rings are not united to either of the metal discs allows them to free themselves with remarkable rapidity so that either on engagement or on declutching the action is very quick.

Greater Power Transmitted by Surfaces Not Plane. To increase the power transmitted by a clutch of given size, either the number of plates must be increased or the form of the surface changed. The latter method was followed on the clutch of the French car "Ours."

The discs of this unusual clutch had a perfectly flat outer portion and a conical inner portion, only the latter taking part in the transmission of power. In this disc form, then, we have the advantage of the disc economy of space, together with the advantages of the cone clutch and the additive gain of running in a bath of oil.

Another form utilizing this principle, and one that is more widely used, is that known as the "Hele-Shaw" so named from its inventor, the famous English scientist, Dr. H. S. Hele-Shaw. This is essentially a flat disc, as shown at *A*, Fig. 256, with a ridge *B* at about the middle of the friction surface; this ridge consists of a portion of the surface, which has been obtruded during the stamping process in such a way as to leave the surface of the ridge in the form of an angle of small height. The angle used is 35 degrees, and this value has been determined upon experimentally as the best. Fig. 256 shows a cross-section through an assembled clutch, which reveals the clutch angle very plainly. In use, the ridges nest one on top of the other; and in the extreme act of clutching, not only the flat surfaces but both sides of the ridge are in contact with the next plate. Thus, not only is the surface for a given diameter increased, but the wedge shape is also taken advantage of.

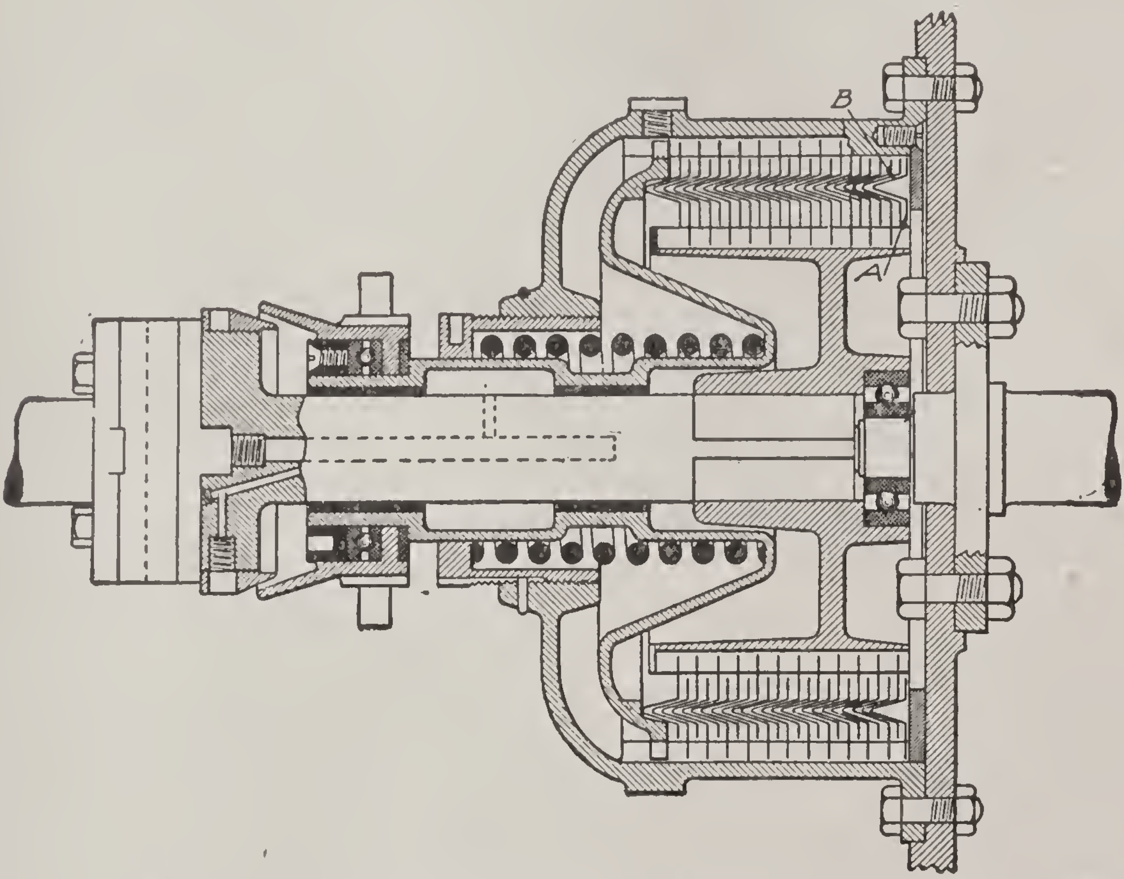


Fig. 256. Hele-Shaw Disc Clutch, Showing Cone Surfaces

Hydraulic Clutches. All the methods of engaging and disengaging the engine at will, as discussed before, have been of a mechanical nature. The hydraulic clutch, on the other hand, partakes more of the fluid nature, although it is operated by mechanical means. Ordinarily, it is in the nature of a pump with a by-pass, the pump working at ordinary speeds to force the heavy liquid, usually glycerine, through the by-pass. To clutch up tightly, however, the by-pass is closed and, the liquid being unable to circulate while the pump continues to operate, the whole device is rotated as a unit. In this case it operates just as any other clutch, but, due to the sluggish action of the fluid, it is slower to respond. Then, too, the grave question of leakage is always present, and the smallest leak puts the clutch entirely out of use. These disadvantages, together with the necessary complications, have retarded the development of the hydraulic form so that there are few of that type in use today.

Magnetic Clutch. All the foregoing clutches present in one form or another very complicated devices for freeing the transmission shaft from the engine shaft, but the magnetic clutch is a device which has simplicity for its foremost argument. The magnetic clutch consists primarily of three parts: the field, usually in the form of a ring; the armature, always of ring shape; and the oil casing shaped to accommodate the other parts, its function being that of a cover. The armature is a simple cast-iron plate of rectangular section, adapted to be drawn into engagement with the field when the latter is energized.

The field, on the other hand, is made up of the back plate, the inner and outer field rings, the magnetizing coil, and the contact rings. In operation, the accelerator is energized by closing the electrical circuit, which sends a current through the field. This magnetism attracts the armature, which then moves laterally, closing the very small gap between the two. The oil in which the whole clutch works prevents it from taking hold suddenly, or gripping, but as this oil film on the two surfaces is gradually squeezed out, the clutch as gradually takes hold.

New Electric Generating Clutch. So great has been the interest in the various electrical mechanisms in the automobile, and so quickly has the public taken up with all these that this has stimulated an entirely new invention, called by its maker, the Vesta

Accumulator Company, Chicago, a centrifugal electric-generating clutch. This name gives a little clue to its action, which is that of a combination of the usual friction clutch and that of the electric-magnetic drag between armature and fields of any electric machine.

In addition to its clutching feature, its ability to drive when partially clutched makes it, in effect, a transmission, so that it is designed to replace the usual clutch, gearset, flywheel, electric generator, and starting motor. It is composed of two parts: an armature, which becomes the flywheel; and a field mounted on the propeller shaft. The former carries an internal commutator, and the latter carries brush holders which hold brushes against the commutator. These brushes are mounted so that the centrifugal force of rotation increases the force with which they press against the commutator. Thus there is a variation from practically no contact up to the maximum, at which point the centrifugal force is so great that field and armature revolve as a solid unit.

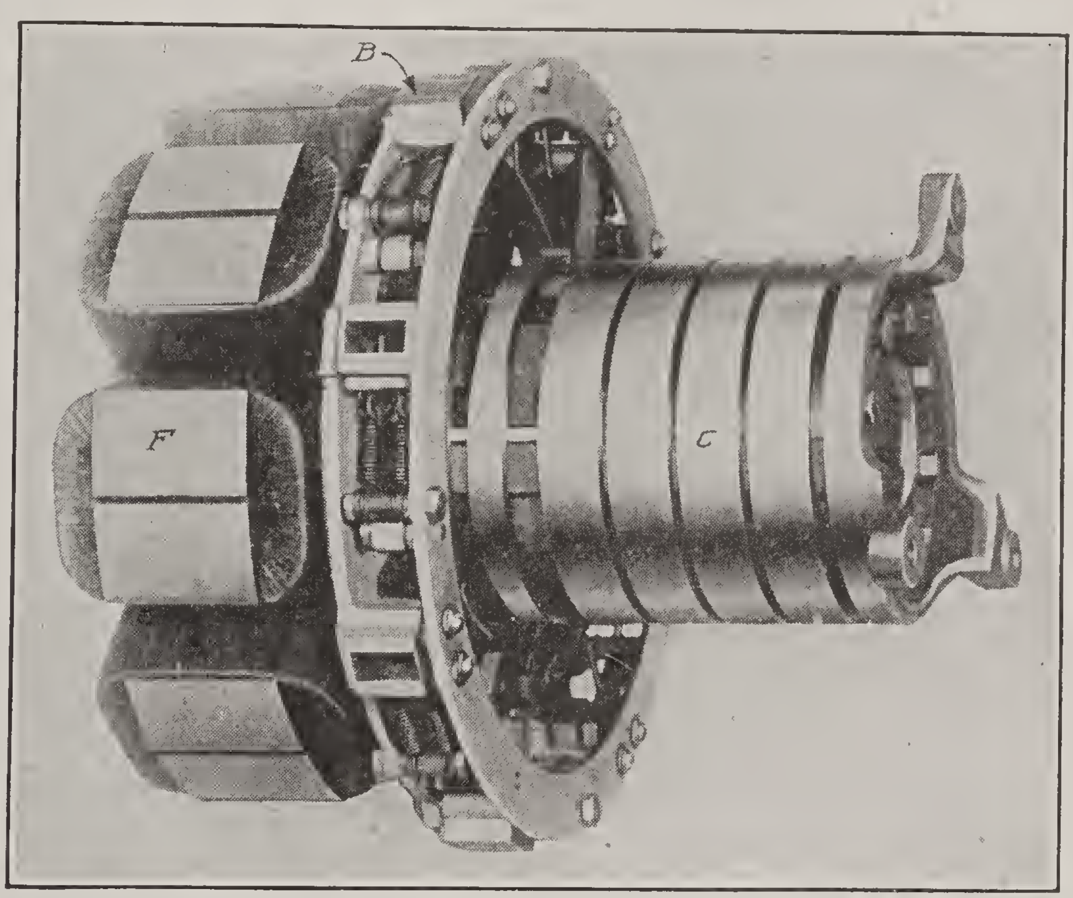


Fig. 257. Field Unit of the Vesta Centrifugal Electric Clutch
Courtesy of Vesta Accumulator Company, Chicago, Illinois

This construction is well indicated in the two illustrations of this device, Figs. 257 and 258. Fig. 257 shows the field unit mounted on the propeller shaft in which *F* is one of six field poles, *B* a brush, and *C* one of the collector rings. Fig. 258 is an external view which shows the clutch assembled. In this illustration the brushes *B* are shown pressed out against the commutator by the centrifugal force.

An automobile built in France—the Ampere—uses the electric-generating clutch construction exclusively, the master clutch being dispensed with in favor of an individual-clutch transmission. The differential is dispensed with, and in its place a pair of magnetic clutches—one for each wheel—are used. The differential action is obtained on curves by decreasing the current to the clutch on the inner wheel up to a certain point, at which it is cut off entirely. This gradual reduction and cutting off of the current is accomplished automatically by the movement of the steering wheel.

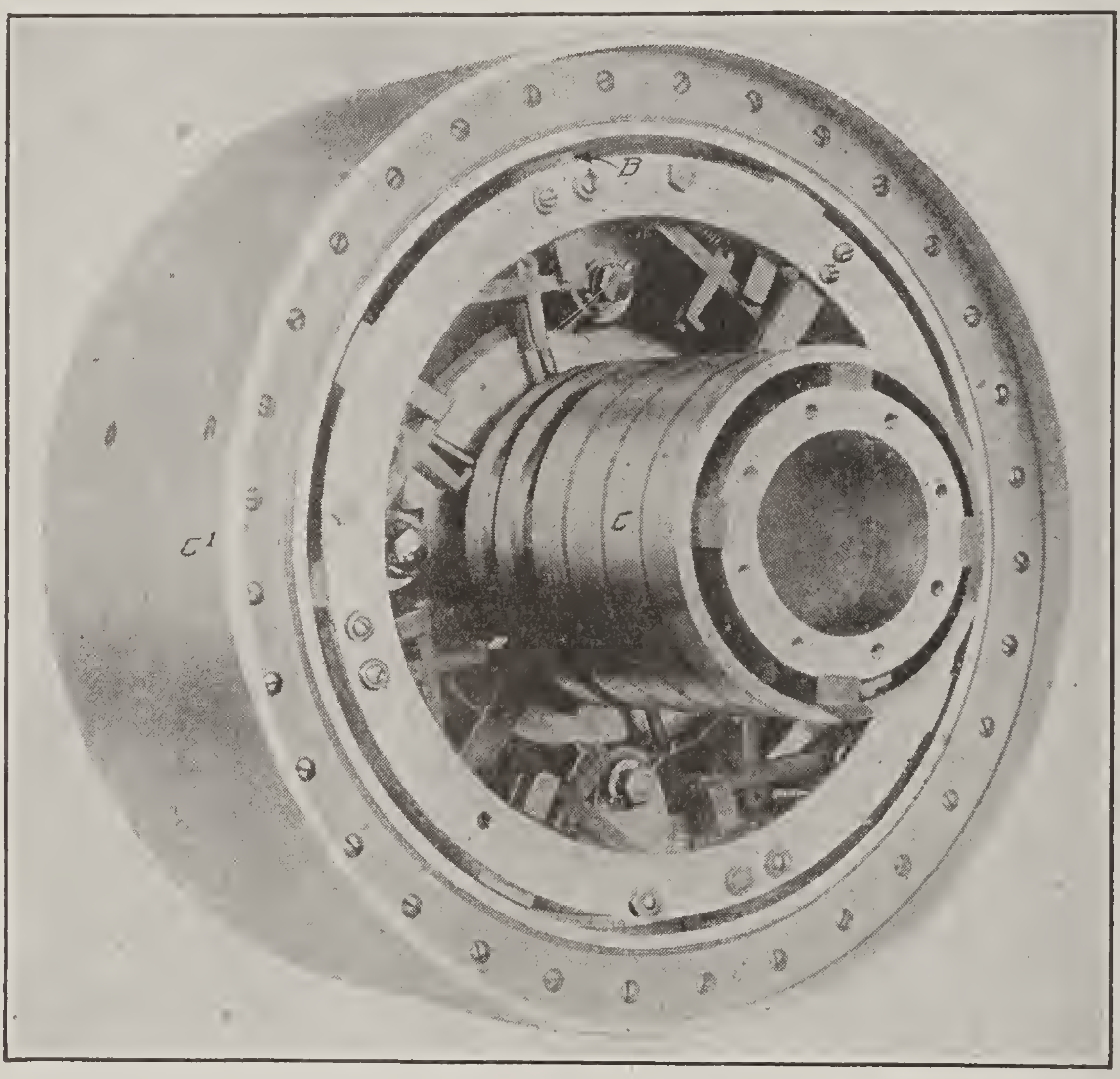


Fig. 258. Assembled Vesta Electric Clutch
Courtesy of Vesta Accumulator Company, Chicago, Illinois

DETAILS OF CLUTCH OPERATION

Methods of Operation. Practically all modern clutches are operated by means of a special pedal moved by the left foot. The pedal is connected to the internal member by means of rods and levers, which compresses the clutch spring or springs and allows the clutch members to separate. This throws the clutch out. To throw it back in, remove the foot pressure from the pedal, and the springs again exert pressure and force the parts together. This action causes them to take hold. There was a time when a considerable number of cars had the clutch so constructed that the pedal held it in and the springs threw it out, just the reverse of the present plan. This method is no longer used, as it necessitated a constant pressure on the pedal while driving—a very fatiguing process.

Gradual Clutch Release. The Dorris clutch, made by the Dorris Motor Car Company, St. Louis, Missouri, Fig. 259, is a new arrangement of the clutch pedal, and its operation is such that the clutch is released or thrown out with very light pressure on the pedal. Pressure on the pedal *A* is transmitted by the shorter lever arm *B*, thus greatly increasing the leverage. This pressure is transmitted to lever *C* and through it to lever *D*, these two being hung on the frame cross member *E*. As *C* is much longer than *D*, there is another multiplying action here. This does not act directly upon the clutch but upon the upper end of the clutch shifter *F*, which is attached to the clutch at *G* and pivoted at its lower end *H*—here again in a multiplying action. The net result of these three multiplications is a combination which will release the strongest and stiffest clutch with a very slight pressure of the foot.

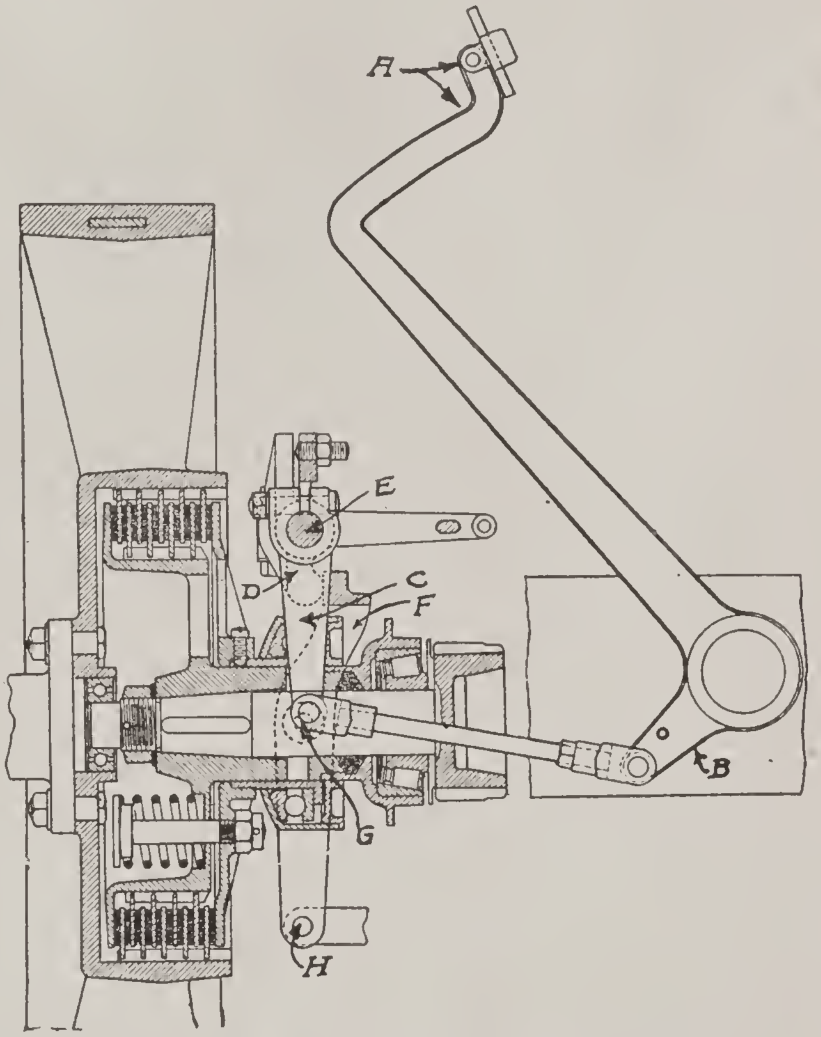


Fig. 259. Multiplying Lever of Dorris Clutch to Make Pedal Pressure Light

Courtesy of Dorris Motor Car Company, St. Louis, Missouri

Clutch Pedals. It has been the general practice in the past to have the clutch pedals separate and distinct, with the service-brake pedal on a concentric shaft occasionally. Now, however, the rapidly growing practice of simplification and elimination, combined with the wide use of the unit power plant, is eliminating the so-called clutch shaft with its bearings and fastenings to the frame, to the clutch operating yoke, and to many other parts. As the Cadillac illustration, Fig. 254, shows and as the Buick drawing, Fig. 260, shows even better, all these shafts, rods, and fastenings can be eliminated and the pedals and levers mounted directly on or in the power unit. In the Buick illustration, the foot brake has a simple rod connection from the ear *A* on the pedal to the brake-operating system, while the hand brake has a similar connection from the extended lower end of the rod *B* to that brake-operating system. In this simple way, perhaps 40 or more pieces are eliminated and their weight saved.

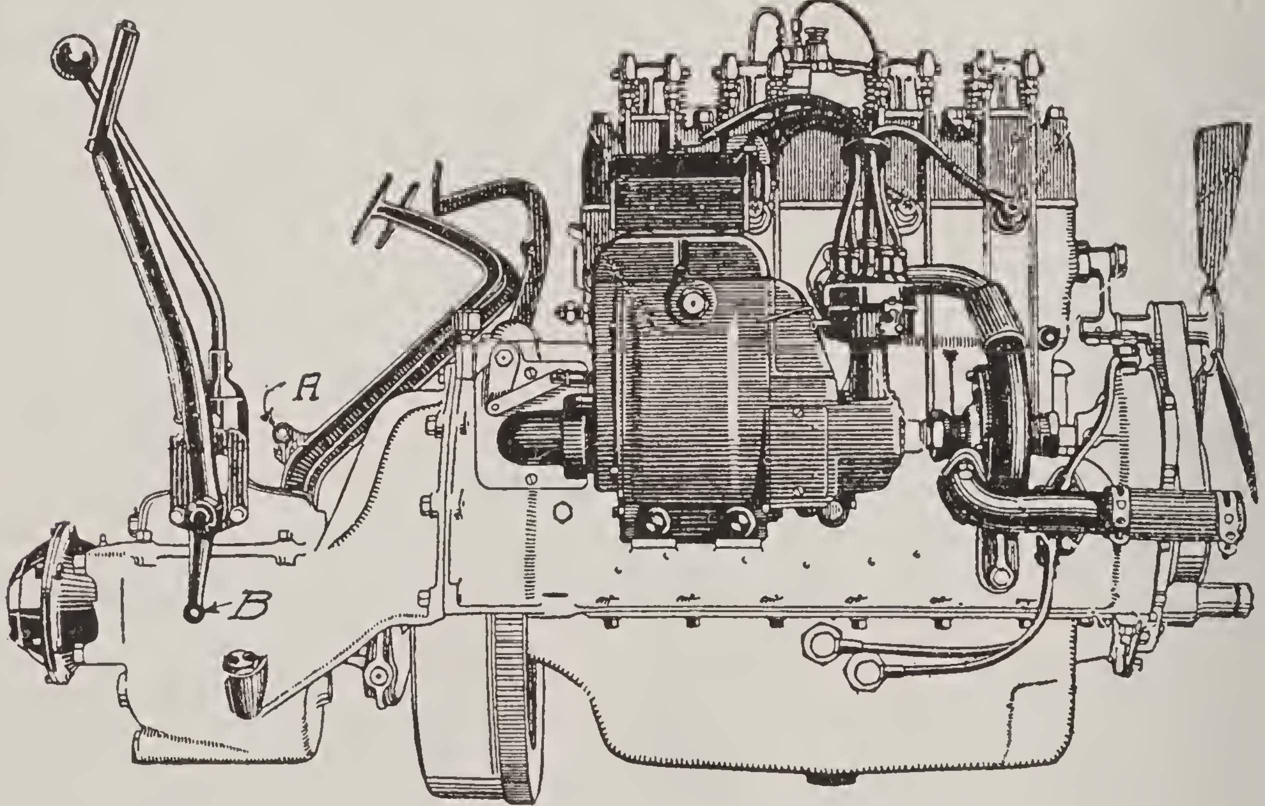


Fig. 260. Unit Power Plant of New Small Buick Four
Courtesy of Buick Motor Company, Flint, Michigan

Clutch Lubrication. As has been previously pointed out, some clutches run in oil, while others run dry. The former type must be kept filled with lubricant at all times. The general plan in such a case is to provide a lead from the engine oiler when the clutch case is separated from the engine case or a connecting means when the two are in one case. In addition to the actual clutching members, there is practically always a sliding member, which must have lubricant of some form, while the thrust bearings to take the thrust of the clutch springs must be cared for. Generally, these two cases are cared for by a pair of grease cups, which are visible in Figs. 247 and 249. The operating rods are lubricated usually by means of small oil holes, either drilled directly into the part or covered with a small oil cup. In those cases in which the clutch runs in oil, it will be noted that a filling plug is provided, by means of which additional lubricant can be poured into the casing, Fig. 256.

Clutch-bearing lubrication is highly important, particularly with clutches like the cone which must be kept free from lubricant and the dry disc in which lubricant is not used. Where the clutch itself runs in oil, it is a simple matter to lubricate the bearings, but in the other cases, oil or grease must be provided from one of three places: from a prolongation of the engine oiling system, as shown in Figs. 246 and 251; from the outside—generally by means of grease cups—as just discussed; or from the transmission end. The last form is used only in unit power plants; combinations of clutch and transmission, as shown in Fig. 253; and in cases, Fig. 256, where the construction allows a grease or an oil cup attachment at the transmission end, the transmission itself being some distance away.

Clutch Bearings. The need for bearings in a clutch depends somewhat upon its nature and location, but regardless of these a thrust bearing is needed for the clutch spring. To explain this briefly, it is known that action and reaction are equal, and opposite in direction. For this reason, when a clutch spring presses the discs or parts together with a force of, say, 100 pounds, there is exerted in the opposite direction this same force of 100 pounds. In order to have something for this to work against, a bearing is used, and since it takes up this spring thrust, it is called a thrust bearing. Not all bearings are fitted to take thrust, as the majority are designed for radial loads only. For this reason a special design is needed.

When the clutch is incorporated in the flywheel, two additional bearings — one for the end of the crankshaft and another for the transmission or driven shaft — are generally needed. The bearings will be noted in Figs. 246, 248, and 249, although the transmission-shaft bearing does not have the clutch combined with the engine but rather with the transmission. In the majority of cases, it will be found that a means of fastening the end of one shaft has been worked out so as to eliminate one bearing. This accounts for the large number which show but two—the thrust and one other. In looking back over the clutches, it will be noticed also that nearly all the bearings are of the plain ball form. This is due in large part to the fact that the plain ball bearings take up the least room for the load carried, both in diameter and width—a contributing reason being the fact that in many cases one of the shafts or parts can be formed to take the place of either the inner or outer ball race.

Clutch Adjustment. Adjusting a clutch, as a rule, is not a difficult task as there are but two possible sources of adjustment—the throw or movement of the operating pedal or lever and the tension of the spring. An adjustment is generally provided for each. When the fullest possible throw of the pedal does not disengage the clutch, an adjustment is required to give a greater throw. If the throw is correct, but the clutch takes hold too quickly and vigorously, the spring pressure can be lessened somewhat to soften down this action. On the other hand, when dropped in quickly, if it takes hold slowly, more spring pressure is needed, and it should be tightened.

Clutch Accessibility. Clutches are made accessible in two ways: by their location on the car and by the relative ease with which they can be removed. Accessibility as to location is less in the various combinations, such as in the unit power plant, housed within the flywheel, or combined with the transmission. Ease of removal is determined by the number and location of the joints (usually universal) used with the clutch.

CLUTCH TROUBLES AND REMEDIES

The very fact that the clutch is a more or less flexible, or rather, variable, connection between engine and road wheels makes it necessary that it be kept in the best of shape. It is rather surprising to the novice with his first clutch trouble to have his motor racing at the highest possible speed and to find his car barely moving, but to the experienced driver it is humiliating.

Slipping Clutch. Slipping is the most common of clutch troubles. This is brought about in a cone clutch by oil, grease, or other slippery matter on the surface of the clutch and can often be cured temporarily by throwing sand, dirt, or other matter on the clutch surface, although this is not recommended. Many times, the clutch leather, or facing, becomes so glazed that it slips without any oil or grease on it. In that case it is desirable to roughen the surface. This may be done by taking the clutch out, cleaning the surface with kerosene and gasoline, and then roughing-up the surface with a file or other similar tool.

In case it is not desired to take the clutch out, or when it is very inaccessible, the clutch surface may be roughened by fastening the clutch pedal in its extreme out position with some kind of a stick, cord, or wire, and then roughing the surface, as far in as it can be reached, with the end of a small saw, preferably of the keyhole type, as shown in Fig. 261. Before starting this repair, it is well to soak the leather with neat's-foot oil. This softens the leather and makes the roughening task lighter.

Many drivers make the mistake of driving with the foot constantly on the clutch pedal. This wears the leather surface and helps it to glaze quickly. The constant rubbing from frequent slipping makes the leather hard and dry.

When a metal-to-metal oiled clutch slips, the trouble usually is in the clutch spring, which is too weak to hold the plates together. To remedy slipping with this type, it is necessary to tighten up the clutch-spring adjustment.

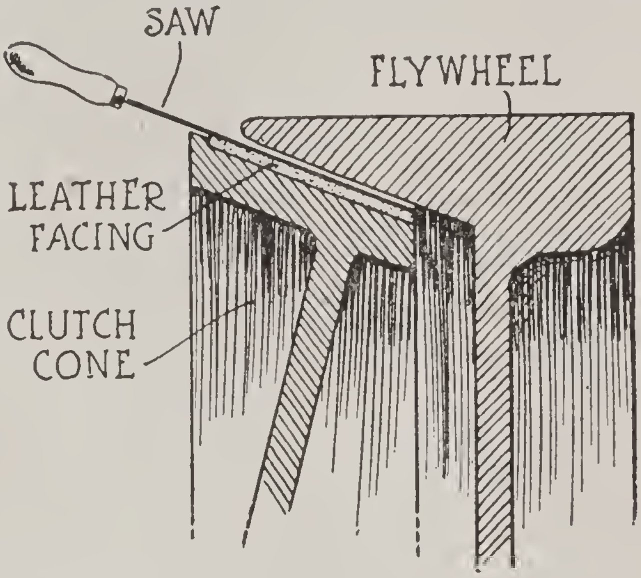


Fig. 261. Method of Roughing-Up Clutch Leather with Saw

Clutch troubles are not always so obvious. In one instance, the clutch slipped on a new car. In the shop, the clutch spider seemed perfect and properly adjusted, also the spring, but to make sure, a new clutch was put in. Still the clutch slipped. To test it out still farther, the linkage was disconnected right at the clutch and then it held perfectly, showing that the trouble was in the linkage. On examination one bushing was found to be such a tight fit that it would not allow the pedal to move freely enough to release the clutch fully. When this was relieved a little, the clutch acted all right.

Replacing Clutch Leathers. Clutches offer many chances for trouble. The most frequent causes are the wear of leather facings with the attendant loss of power, and weak springs. Weak springs may be cured by screwing up on the adjusting nut or bolt provided.

Slippery leather may also be corrected by washing first with gasoline and then with water, finally roughing the surface with a coarse rasp and replacing only after the leather is thoroughly clean. Dry leather is fixed by soaking in water or neat's-foot oil. It should be replaced while still moist, and copious lubrication will keep it soft.

The greatest problem in replacing a worn, charred, or otherwise defective leather lies in getting the right layout for the form of the new leather the first time. It must be remembered that the surface is a portion of a cone and, therefore, its development is not easy. It is attacked in this manner: Prepare the cone by removing the old leather and all rivets, cleaning out the rivet holes, and providing new rivets. Measure the cone, taking the diameters at both the large and small ends and also the width. Take a large sheet of paper and lay off upon it a figure similar to *ABCD*, Fig. 262, drawn to exact scale and having for its dimensions the three measurements just obtained, viz, the large and small diameters and the width of the cone. This figure represents the projection of the cone in a flat plane. Bisect the line *AD* and draw the center line *EF* at right angles to *AD*. Prolong the two tapered lines *AB* and *DC* until they meet the center line as at *G*.

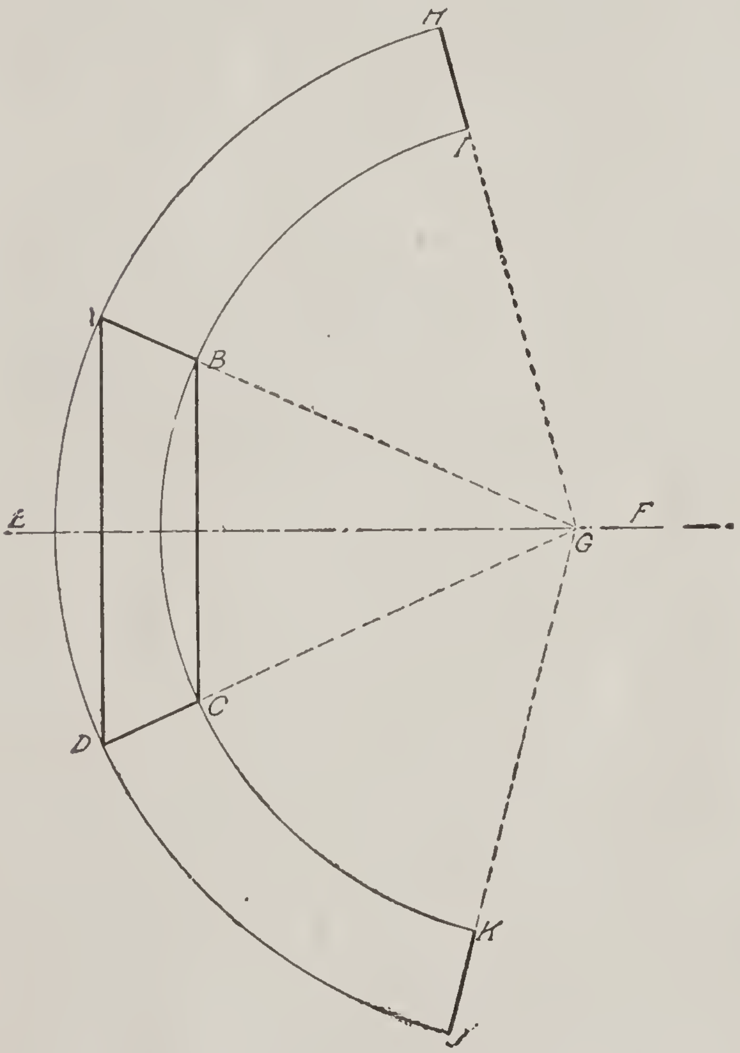


Fig. 262. Diagram Showing How to Cut Clutch Leathers

The point *G* represents the apex of the cone if it were complete, and hence any circular arc with the correct radius, drawn from this point as a center, will be a correct projection of the development of that portion of the conical surface. With *GA* and *GB* as radii, draw the two circular arcs *HADJ* and *IBCK*, also draw the radial lines *HI* and *JK* to pass through *G*. The enclosed figure

HIBCKJDAH may then be cut out and used as a pattern from which to cut out clutch leathers. If the distances *AH* and *DJ* be made approximately equal to or slightly more than *AD*, the pattern will a little more than encircle the cone clutch.

After the leather has been cut out, it should be prepared by soaking in water or oil, according as its surface is fairly soft or rather harsh. In either case, it must be well soaked, so as to stretch easily. In putting it on the cone, one end is cut to a diagonal, laid down on the cone, and riveted in place. Next, the leather is drawn down tightly past the next pair of rivet holes, which are then driven into place. This is continued until the strip is secured. The leather is now wetted again, for, if allowed to dry off immediately, the shrinking action will break it out at most of the rivet holes and render it useless. By drying it out gradually, a taut condition may be arrived at without this danger.

Handling Clutch Springs. Clutch springs, like the valve springs mentioned previously, are mean to handle and compress. The best way is to compress and hold them compressed until needed. For this purpose, a rig similar to that described for valve springs should be made but of stiffer stronger stock. A very good one can be made from two round plates, one small, and the other of larger diameter with a pair of **L**-shaped bolts through it. The spring is placed between the two, with the ends of the **L**'s looped over the smaller plate, and then, by tightening the nuts on the bolts, the spring is gradually compressed.

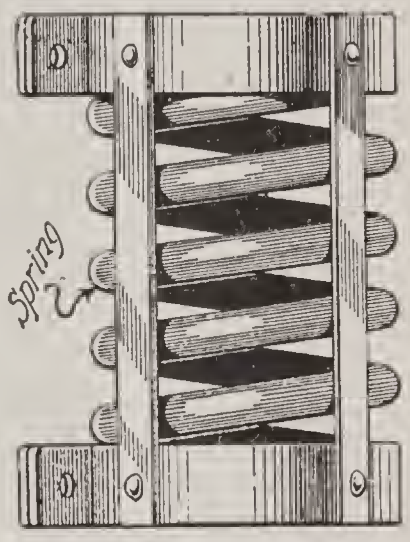


Fig. 263. Type of Clutch Spring Holder Which Works by Friction
Courtesy of "Motor World"

An excellent device for holding clutch springs consists of a simple pair of metal clamps which are joined together by three or more short metal bars, as Fig. 263 shows. If one particular clutch spring is handled continuously, the length can be made to fit this best, otherwise it will have to be made of any convenient length. The inside diameter of the clamps when fully open is greater than the outside diameter of the spring. The clamp is set in a vise or on a drill press and the spring set inside of it. Then the spring is compressed by working the vise handle or by lowering the drill-press spindle. When compressed down to the length used in the car, the ends of the clamp are tightened and the spring is held by friction. Then the spring can be handled readily, using one of the metal bars as a handle. It is put into place, and then the retaining screws can be loosened and the clamp removed.

Fierce Clutch. A fierce clutch is one that does not take hold gradually but grabs the moment the clutch pedal is released. In a metal-disc clutch, this is caused by roughened plate surfaces and insufficient lubricant, so that. instead of the plates twisting gradually across each other as the lubricant is squeezed out from between them, they catch at once and the car starts with a jerk. On a cone clutch, this fierceness is produced by too strong a spring, too large a clutching surface in combination with a very strong spring, or a hard or burned clutch surface or both.

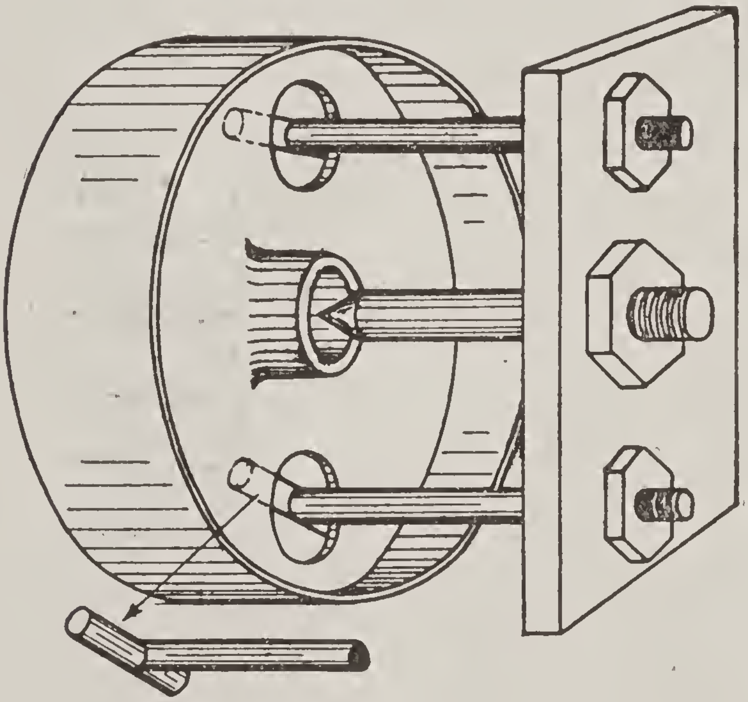


Fig. 264. Simple Rigging for Removing Ford Clutch Disc

Ford Clutch Troubles. There are now so many Fords in use that the average repair man feels justified in making special apparatus or tools to save time or work in Ford repairs. For one thing, the clutch-disc drum frequently needs removal and this is a difficult job. By means of a simple rigging, however, consisting of a plate and a few bolts, it can be taken off in a few moments and with little trouble. It will be noted from Fig. 264 that the rigging is but a modified form of wheel puller. It consists of a $\frac{1}{4}$-inch plate of steel with three holes drilled in it for three bolts. The two outside ones have T-head ends and have to be specially made, and made carefully, as this T-head must slip through either one of the oval holes in the web of the drum. When this is done, it is straightened up so as to stand at right angles to the drum and is thus in a position to press firmly against the drum from the inside. There are nuts on the center bolt on both sides of the plate, but the drawing shows only that on the outer end. When the T-bolts are in place, the center bolt, which is slightly pointed and preferably hardened on the end, is screwed down so as to come into contact with the end of the clutch shaft. After tightening the center bolt, the T-head bolts are tightened until they pull the drum off the shaft.

Clutch Spinning. A trouble which is bothersome but not dangerous is clutch spinning. This is the name applied to the action of the male clutch member when it continues to rotate, or spin, after the clutch spring pressure has been released. With the male member connected up to the principal transmission shaft and gear, as is often the case, these members continue to rotate with it. This gives trouble mainly in gear shifting, for the member which is out of engagement is considered to be at rest or rapidly approaching that condition. When at rest, it is an easy matter to mesh another gear with this one; but when this one is rotating or spinning, it is not so easy, particularly for the novice.

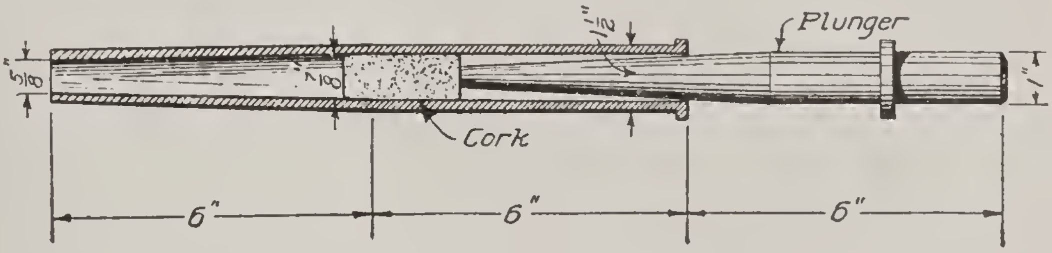


Fig. 265. Simple Device for Inserting Corks in Clutches

Clutch spinning may be caused (1) by a defect in the design, in which case little can be done with it; (2) by a defect in construction, as in balancing, for instance, which can be corrected; or (3) it may be due to external causes, as, for instance, in a bearing which has seized, owing to a lack of lubricant, etc.

In any case, the best and quickest remedy is a form of clutch spinning brake. This may consist simply of a small pad of leather or of metal covered with leather so located on the frame members that the male drum touches against it when fully released. Or it may be something more elaborate as to size or construction or both. On many modern cars, in fact on practically all good cars, some form of clutch spinning brake is fitted. Thus, the Hele-Shaw design provides at the left end, Fig. 256, a metal cone of small diameter, while Fig. 255 shows flat concentric discs *19* of the Locomobile clutch.

Cork Inserts. When cork inserts are used in a clutch, the insertion of new corks is not an easy job. A cork is a difficult and unhandy thing to work with, and above all to hold straight and true while applying longitudinal force to it. By making up a special tool with a tubular member having an inner taper, into which the corks are forced by means of a special plunger which forms the other part of the tool, this is simplified considerably. This tool is shown in Fig. 265, with such dimensions as would be needed for a $\frac{7}{8}$-inch cork. It is advisable to make the small end of the tube $\frac{1}{8}$ inch smaller than the cork, as this amount provides the proper compression. After being soaked in water for 10 or 15 minutes, the cork is dropped into the large end of the tube, and, with the small end in place against the cork opening in the clutch, a single stroke of the plunger will force the cork through the tool, incidentally compressing it into the hole in the clutch. With a few handlings any clever mechanic can soon become expert in the use of this tool.

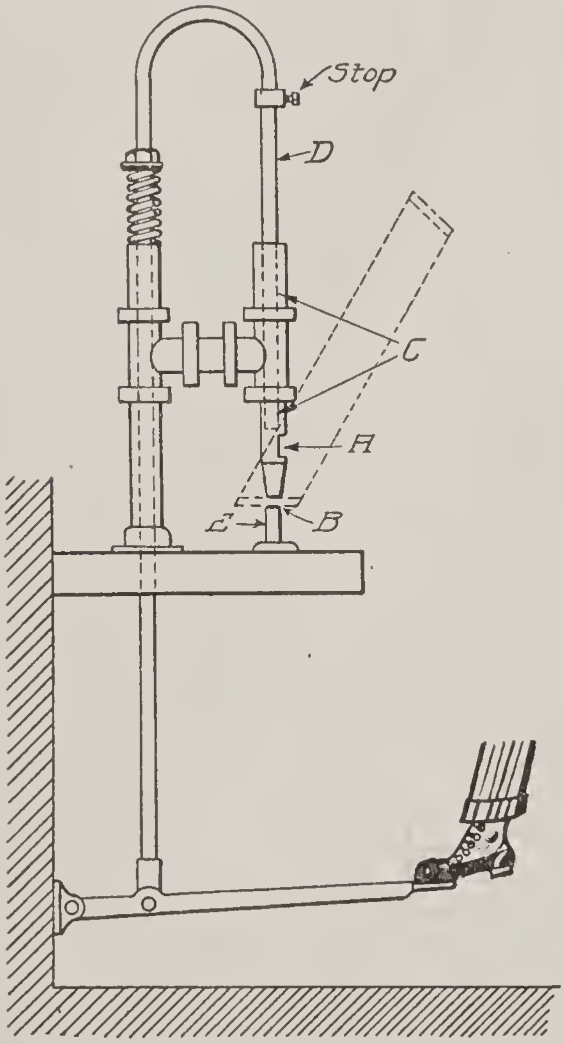


Fig. 266. Machine for Handling Cork Inserts Quickly
Courtesy of "Motor World"

A more elaborate device, but one which works more quickly where there is a great deal of this work, is shown in Fig. 266. This is not an expensive machine—the original of this sketch was home made. The framework is made of standard pipe fittings, the spring is a valve spring, and the rods are cold rolled steel. Only a few pieces such as the working member *C* were specially made. The working member is made with a slot at *A* into which the corks are inserted. When the pedal attached to the rod *D* is pressed, it brings the rod down and forces out the cork at *B*. At point *B*, the clutch resting on the anvil *E* is held ready. The stop limits the downward movement, so a strong stroke of the foot will just push the cork into the hole flush and no more. The lower end of the working member is made with a taper so as to compress the corks about $\frac{1}{8}$ inch, as mentioned before. They should be soaked in water just the same as when using the hand tool.

In Fig. 267, several other common clutch troubles and their remedies are suggested; the parts shown in the illustration, however, are in excellent condition, in fact, new.

When the right kind of clutch discs for a multiple-disc form are not on hand, new discs can be cut from leather to answer the purpose by means of the gasket cutter, shown in Fig. 268. This cutter consists of a pair of steel L-shaped arms, preferably forged, with points sharpened enough to cut the leather or the gasket material. The clamp has a point for the center of the circle on its under side, while the actual clamping is done by the bolt or screw with wing head. To use for clutch discs, set the inner, or shorter, member to the radius of the inside of the outer discs and the outer, or longer, arm to the radius of the outside of the inner discs. By pressing down hard on the arms and rotating them at the same time, an annular ring will be cut out which will fit exactly. One hand should be held on or near the center, while the other hand supplies the pressure and rotating motion on the cutting ends. It should not be expected that the points will cut through in one revolution; on the contrary, the first time around will just mark out the section and it will need from

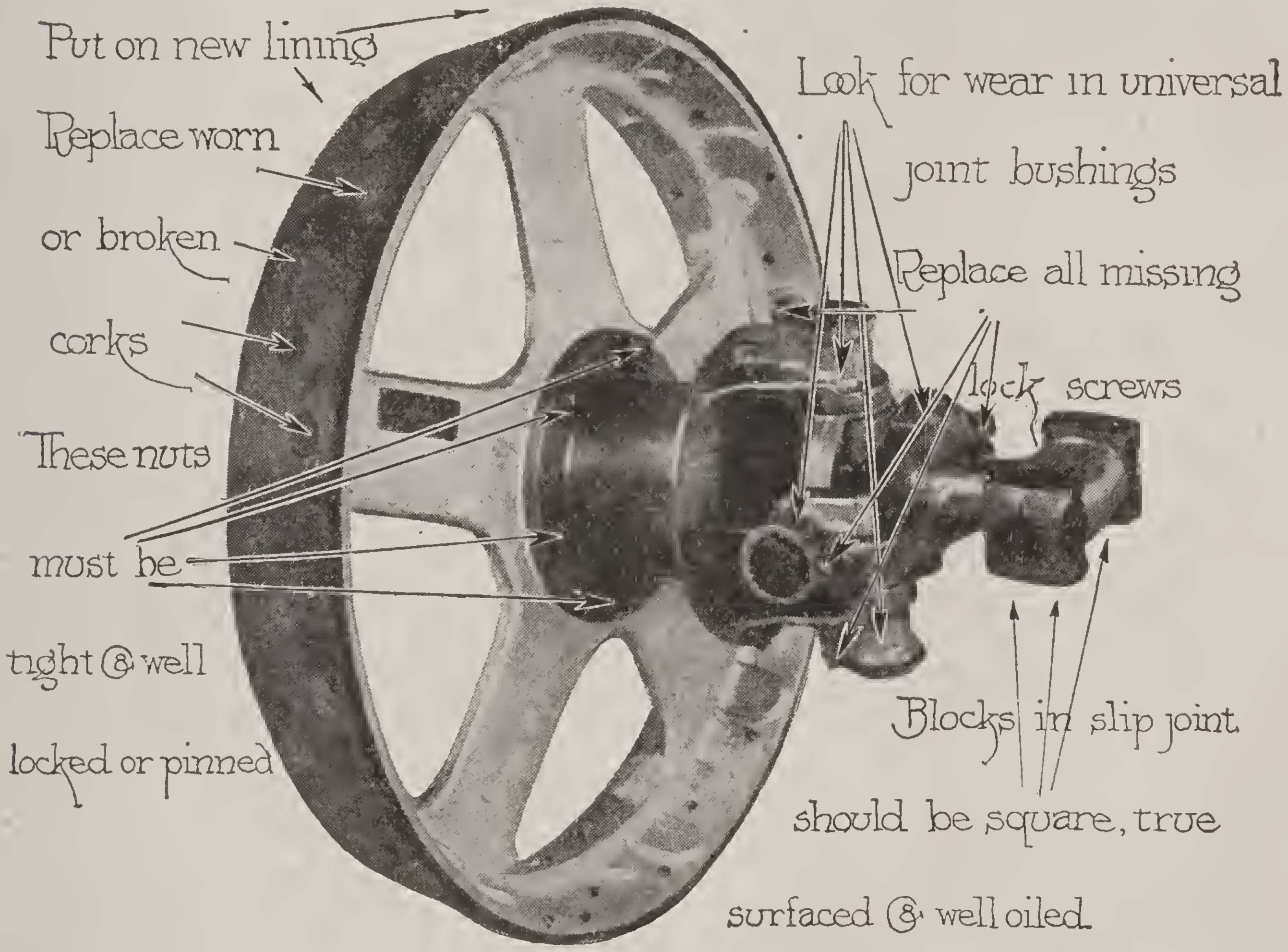


Fig. 267. Clutch Troubles Illustrated

6 to 10 revolutions, with heavy pressure, to cut a leather disc. In time, the workman will become skilled in the use of this cutter and have a knowledge of its limits, as well as of the method of keeping it in good cutting order.

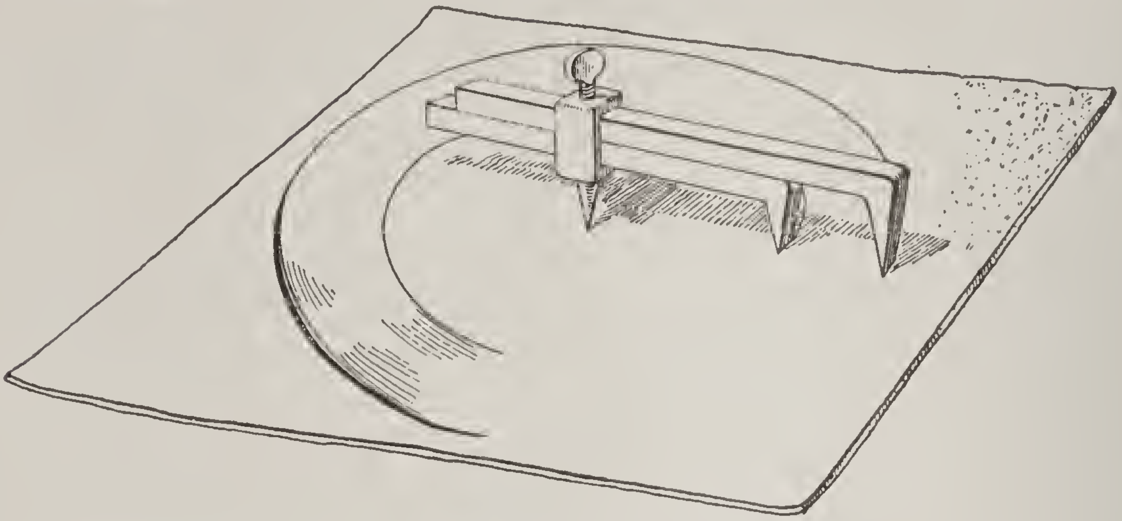


Fig. 268. Method of Cutting Facing for Disc Clutches in an Emergency
Courtesy of "Motor World"

Adjusting Clutch Pedals. Some cars are made with adjustable clutch pedals so the long- or short-legged driver can set the length of these to suit, but when no adjustment is provided and it is desired to change the length, some figuring must be done. To shorten a non-adjustable pedal, the best way is to take it out of the car and bend it somewhat on the order of the dotted lines in Fig. 269. The idea is to make the same amount of metal take a roundabout and longer path. In doing this, the workman must be governed largely by what the floor boards and the other parts of the mechanism in the immediate vicinity will allow. The bend must be made so as to allow the pedal to work in the same slot. If necessary, cut the slot a little longer, but first consider the result before bending the pedal.

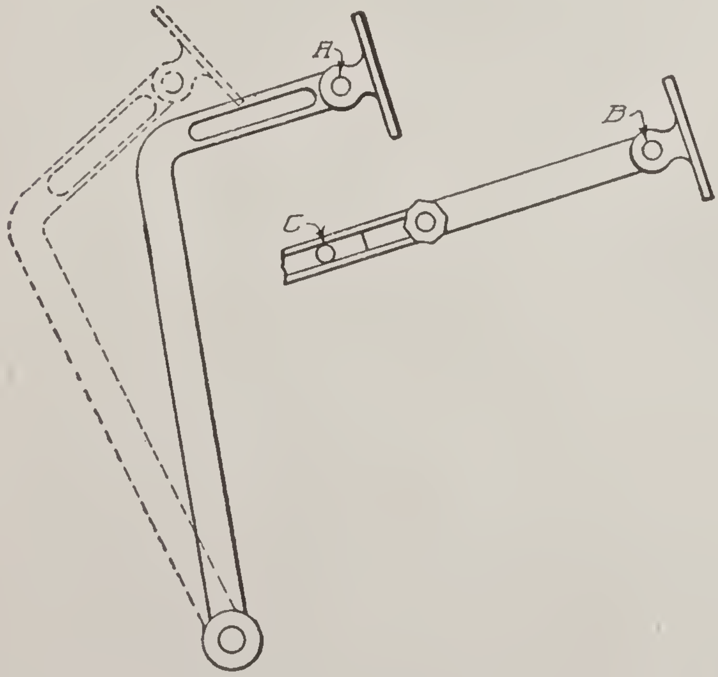


Fig. 269. Schemes for Shortening or Lengthening Clutch Pedals to Fit Driver

On the other hand, when the pedal is too short, the pad can be removed from where it is bolted on at *A* and a pair of steel strips cut so as to fit into the two sides of the pedal shank and brought together at the other end. These are bolted in at A, where the pad was formerly, and the pad moved out to the new end at B. In some such cases, where the sides of the pedal shank offer no groove to help hold the steel strips, it is necessary to put another bolt through them, as at C, to prevent the whole addition swinging about A as a center.

Clutch Troubles Outside of Clutch. Frequently, there is trouble in the clutch when the basic reason for it is outside of the clutch entirely. Thus, failure of a clutch to engage or disengage properly is often the fault of the connecting rods and levers; wear in the clutch collar or in other parts; or the emergency-brake interlock may have been fitted so close that as soon as the rods are shortened once or twice to compensate for wear, it stands in such a position as to throw the clutch out slightly although the latter appears to be fully engaged.

Another clutch trouble outside of the clutch is apparent slipping at corners, especially at turns on grades. On a turn—the road being cambered—the frame is distorted, especially with the combination of curve and grade. This may be sufficient to throw the clutch and driving shaft out of alignment just enough so the clutch face will not make full contact. This is most noticeable on cars with a single universal joint, in which case the distortion of the frame has more effect on the driving shaft. Similarly, a car with an unusually light or flexible frame will show this trouble very often, as the combination of curve and grade is too much for the light frame.

Summary of Clutch Troubles

Throwing in Clutch. Do not throw clutch in suddenly and cause rear wheels to spin. Such action is destructive to tires and throws great stress on the entire mechanism of the car.

Lubricating Multiple=Disc Clutches. These are best lubricated by injecting oil into the opening for that purpose by means of an oil gun. A very light lubricating oil should be used.

Multiple=Disc Clutches Failing to Hold. Inject three or four gunfuls of kerosene into the clutch housing and run the engine a little, thereby washing out the plates of the clutch. This will cut the gum caused by the oil. If, after this treatment, the clutch squeaks or takes hold too suddenly, lubricating oil may be added.

Loss of Power. This is noticeable in changing from intermediate to high gear, in climbing hills, or in running through muddy or sandy roads. The trouble is often the result of the clutch slipping. The remedy is to clean the clutch with gasoline and, if the clutch is leather-faced, to apply castor oil after cleaning. Castor oil should never be used on the multiple-disc clutch.

Failure of Clutch to Take Hold. This may be owing to a broken or weakened clutch spring, the clutch leather may be damaged, clutch shaft may be out of line or bent, leather may be gummed, or bearing may be seizing.

TRANSMISSION GROUP

Primarily, the clutch is used to allow the use of change-speed gearing; or, stated in the reverse way, the form of the transmission determines whether a clutch must be used or not, there being cases in which it is not used. Thus, where the frictional form of transmission is used, no clutch is necessary; the frictional discs act as a clutch and render another one superfluous. So, too, with the form of transmission known as the *planetary gear,* no master clutch is needed.

On the other hand, the reverse of this does not always hold. Any form of clutch may be used with the various other forms of transmission, as the sliding gear; in fact, in actual practice every known kind of a clutch will be found coupled with the sliding-gear transmission.

Classification. Broadly considered, there are five classes of transmissions used. In cases where the use of any one of these forms eliminates the final drive, this from its very nature does not alter the facts but simply calls for a different and more detailed treatment. The five classes are:

(1) Sliding gear { Operated in various ways but usually selective
(2) Individual clutch
(3) Planetary, or epicyclic
(4) Friction disc (various arrangements)
(5) Miscellaneous

The features of the 1917 transmissions which stand out from previous years are: reduced sizes; simpler, lighter construction; greater compactness and greater accessibility. Perhaps the most noticeable trend has been toward the unit power plant which has helped materially to make transmissions smaller, lighter in weight, and more simple, with unusual compactness. This very compactness has brought with it a stiffness which has rendered less repairs and adjustments necessary, despite lighter weight. The smaller sizes have brought about the simplification and lighter weight, and in turn have been produced in answer to the popular demand for lighter weight cars. In part, simplification has been produced by unit power plants, now so popular.

SLIDING GEARS

General Method of Operation. Of the different types of sliding gears, the first two subdivisions are not very closely marked, but blend somewhat into one another. The only real difference between them is the method of operation, the names serving to indicate the distinctive characteristics. Thus, in a selective gearset, it is possible to "select" any one speed and change directly into it without going through any other. So, too, in the progressive form of transmission, the act of changing gears is a "progressive" one, from the lowest up to the highest, and *vice versa.*

Selective Type. With the selective method of changing gears, it is possible to make the change at once from any particular gear to the desired gear without passing through any other. Of course, the car will not start on the high gear any more than in the other case, but shifting into low for starting purposes is but a single action, accomplished quicker than it can be told. So, too, when the car has been started, it can be allowed to attain quite a fair speed and the change to high made at once without going through the intermediate gears.

Progressive Type. Progressive gears, which are now little used, operate progressively: from first, or low, to second and from second to third, or high; in slowing down, from third to second to first and in this way only. This leads to a number of troublesome occurrences; thus, in stopping, it is necessary to gear down through all the higher speeds into low. If this is not done, when it is next desired to start the car, it will be necessary to start the engine, throw in the clutch, drop from the gear in mesh to the next lower, from that to the next, and so on down to low, throwing the clutch out and in for each change of speed. When first is reached, the car may be started. After starting, it is then necessary, in order to obtain any measurable speed with the car, to change back up the list, from low to second, from second to third, and so forth. In this way the progressive gear is disadvantageous, since its use means much gear shifting; but, on the other hand, the shifting is very easy for the novice to learn, as it is a continuous process, all in one direction.

Modern Selective Types. To present some modern selective types of gear boxes and point out their various differences, advantages, and disadvantages, refer to Fig. 270. This type shows the three-speed selective gear used on the Cadillac cars, which is but slightly modified from the type which has been used by this concern for three years. This change should be noted, however; the layshaft, which formerly was on the same horizontal level as the main shaft, is now placed directly below it. This makes a higher but narrower gear box, that is, instead of being wide and fairly flat, it is now high and narrow. The placing of the shifting levers on the cover, directly over the center, has aided in making the gearset more compact than formerly. In it there are two shifting gears, one gear carrying a set of dogs cut into its face, which mesh with a similar set on the main driving gear to give the direct drive. The gear portion of this member meshes with another gear for second. The second shifting member meshes with one gear on the layshaft for low speed

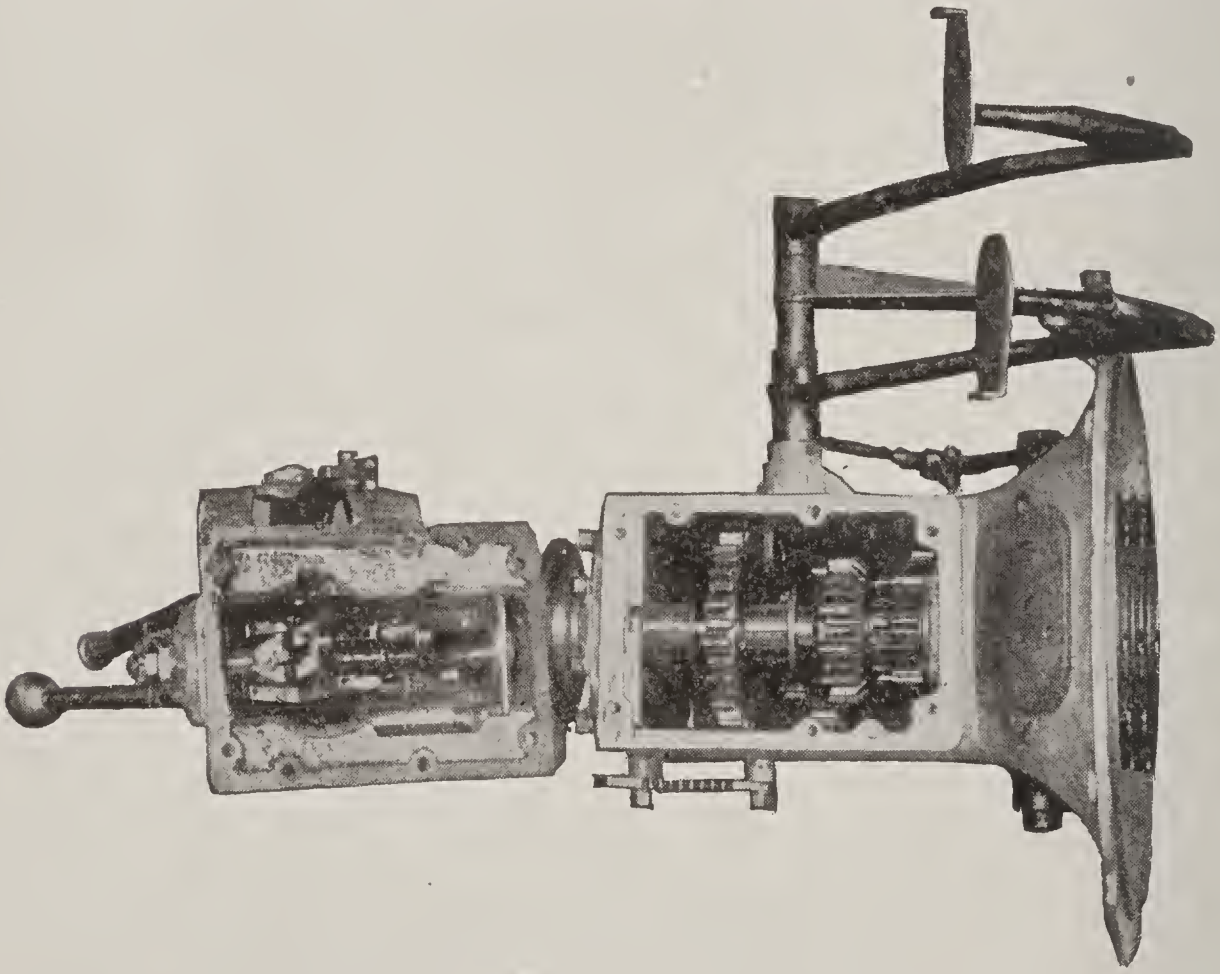


Fig. 270. Cadillac Transmission and Housing

and with another on the third shaft for reverse. The reverse gear is at all times in mesh with the fourth layshaft gear, so that on reverse the drive is through five gears instead of four. On high gear the drive is through the dogs, the layshaft being driven, of course, but silently, as it transmits no power.

Four-Speed Type with Direct Drive on High. One of the tendencies of recent years has been the gradual change toward more speeds, as shown by the increasing use of four-speed gear boxes.

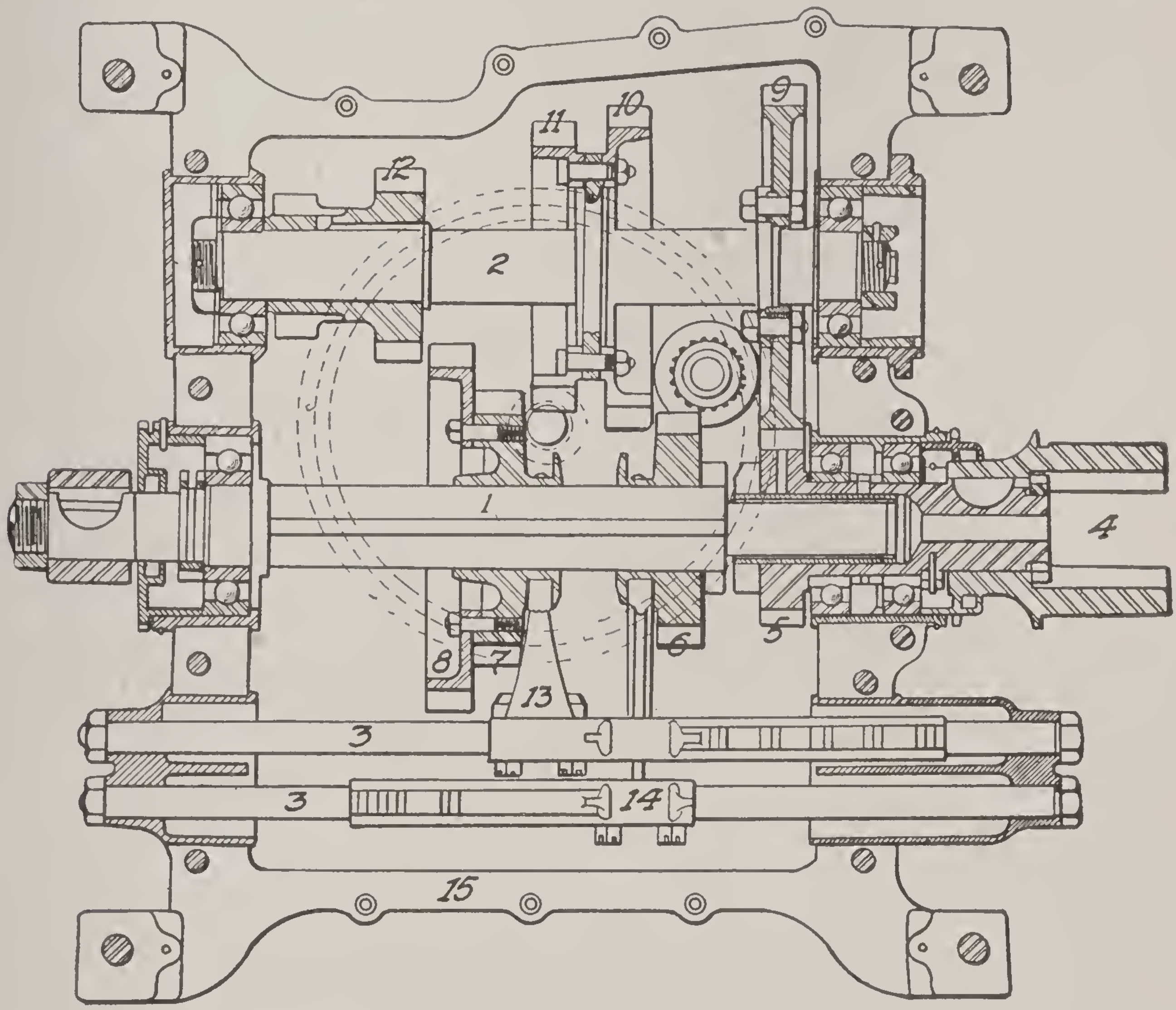


Fig. 271. Sectional Plan Drawing of the Locomobile Four-Speed Transmission
Courtesy of Locomobile Company of America, Bridgeport, Connecticut

Other indications of this change have been the two-speed axle, which gave double the number of gear-box speeds, with the ordinary three-speed and reverse transmission; and the electric transmission, which affords seven forward and two reverse speeds.

Following this increase of speeds, the multi-cylinder motors and downward price revisions of the early part of 1916 brought about a combination which almost eliminated the four-speed gear box or at least removed it from all but the most expensive of cars and from many of those. It is claimed that the eight- and twelve-cylinder motors have so much power and flexibility that a fourth speed is rendered unnecessary. The four-speed gear box is more expensive than the three-speed box, and the lowered prices of cars have been instrumental in preventing its continued use. At the same time, there was considerable lightening of weight all over the chassis, and the four-speed gear box had to go out of all but the biggest cars on account of its greater weight.

Fig. 271 is a sectional plan of one of the few four-speed gear boxes left. In this drawing it will be noted that the two-gear shafts, as well as the operating shafts, lie in the same horizontal plane. The halftone reproduction of the photograph of this drawing, Fig. 272, shows the location of the shafts even more plainly and will, perhaps, be of more use to the average reader. Both forms show the arms which project up to attach this unit to the frame. The cover, which is a light easily removed aluminum member, is taken off from above after the floor boards are lifted out. This arrangement makes for accessibility and eliminates any need for lying on the ground while working on the transmission gears or shafts, should such work be necessary.

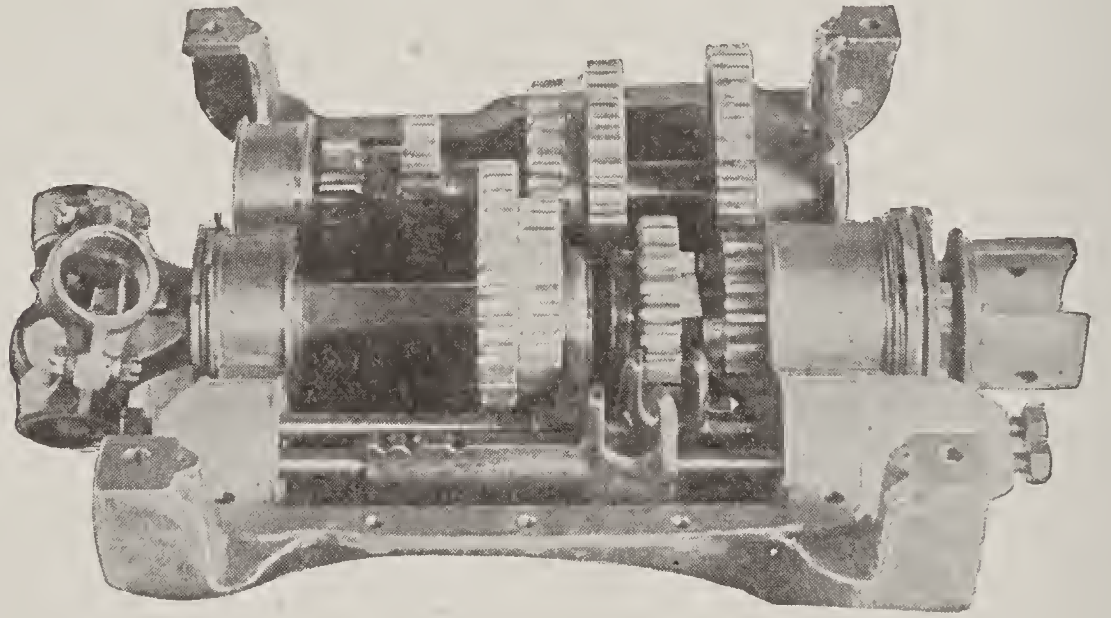


Fig. 272. Photographic Reproduction of Locomobile Gear Box Shown in Section in Fig. 271

The form of final drive alters the construction of the transmission very materially. Formerly, when all final drives were of the double-chain form, it was customary to include the differential, bevel gears, and driving shafts in the gear box. Now that the chain has gone out, this construction is found only when the gear box is a unit with the rear axle.

Four-Speed Type with Direct Drive on Third. In all the transmissions shown and described thus far, the direct drive has been the highest speed. By referring back to Fig. 253, which show the Winton four-speed gear box, as well as the clutch, a point of difference will be seen. This has the direct drive on third speed, fourth being a geared-up speed for use only in emergencies, when the very highest rate of travel is required, and when a little noise more or less would make no difference. This arrangement of the direct drive and silent speed has long been a debated point, some designers favoring the direct-drive type with an over-geared speed for occasional use, while the opponents of this method say that this construction practically reduces the transmission to a three-speed basis, the fourth being so seldom used that it is practically negligible. They say, also, that the modern motor can attain a high enough speed, on the one hand, and is flexible enough, on the other, to permit its being used with the high-gear direct drive upon almost all occasions.

Transmission Location. There are but four recognized positions for the transmission in the modern car. These are: (1) unit with the engine (unit power plant), (2) amidships in unit with clutch or alone in a forward position, (3) amidships in unit with forward end driving shaft or in a rear position, and (4) at the rear in unit with rear axle.

Unit with Engine. The unit with the engine type is illustrated in an excellent manner in Fig. 273, which shows the eight-cylinder Northway motor, cone clutch, and three-speed transmission. Some idea of the compactness of this outfit, which is shown exactly as used on the Oakland car, can be gained from comparison with cylinder bore and crankshaft size, the motor being $3\frac{1}{2}$ by $4\frac{1}{2}$ inches. The noticeable features of the transmission, aside from its compactness, are the use of double row ball bearings on the splined main shaft, with a Hyatt roller form for the spigot bearing (free end of main shaft) and very long plain bronze bushing for the countershaft unit, the latter being made as a single piece rotating on a single bearing around a straight fixed shaft. The countershaft, or layshaft, as it is sometimes called, is placed below the main shaft.

Another example of the unit with engine type is seen in the Grant-Lee three-speed gear box, Fig. 274, as utilized in the Hackett car. This is unusually small and compact, as will be noted by comparing the size of the unit with the operating levers and pedal. While

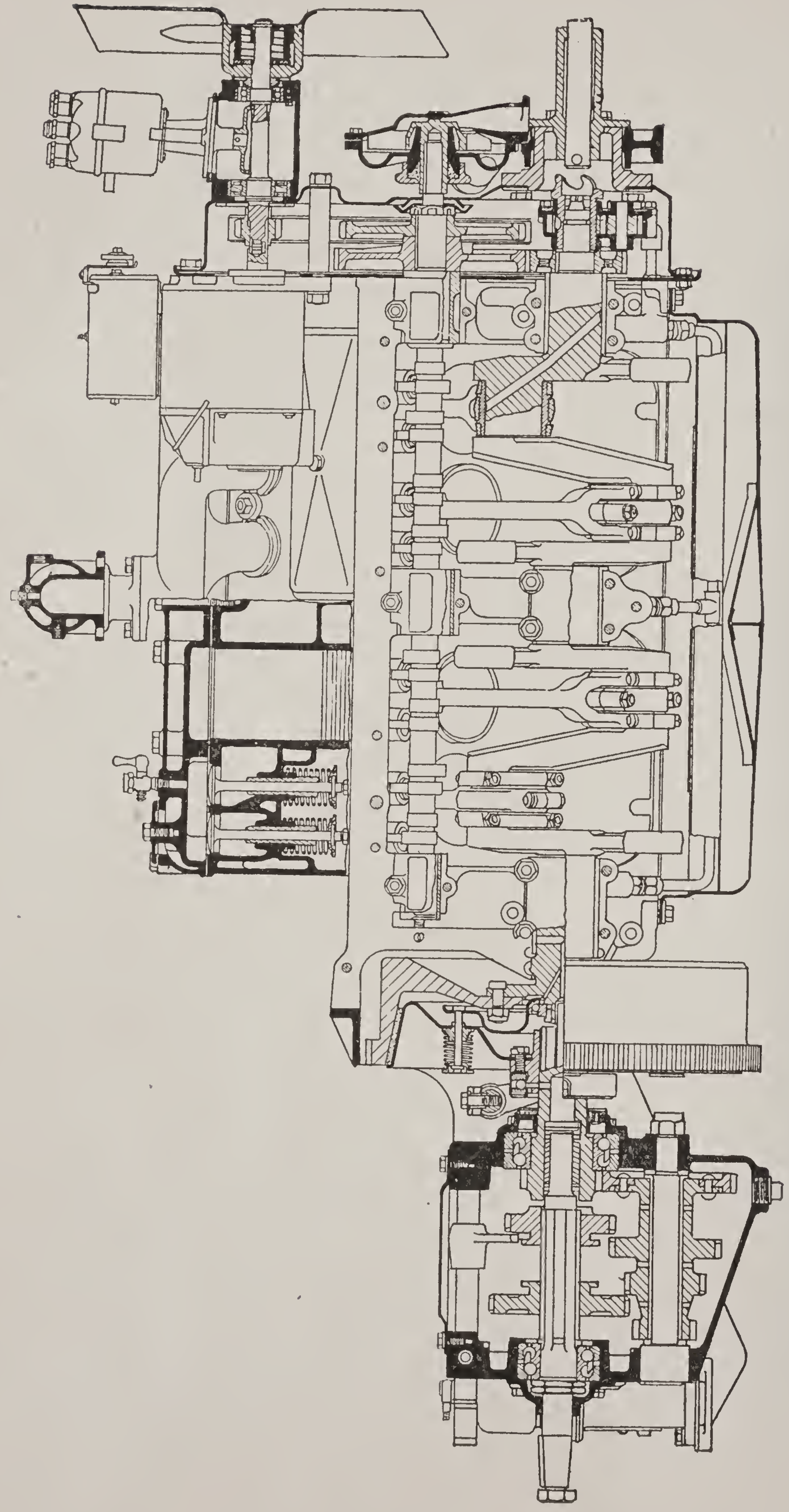


Fig. 273. Unit Power Plant of Oakland Eight-Cylinder Car
Courtesy of Oakland Motor Car Company, Pontiac, Michigan

the clutch is not shown, its housing is, also the flange which attaches it to the flywheel housing to complete the power unit. A third example of the engine-unit power group is shown in Fig. 275, which shows the flywheel, clutch, and transmission of the Peerless eight. This unit transmits many times the power of the Hackett unit and is therefore much larger. In this unit the bearing arrangement is rather unusual, as roller bearings of the taper form are used on the main shaft, a straight roller for the spigot bearing, and plain ball bearings for the layshaft. The shortness and large diameter of the shafts should be noted.

Additional transmissions in a unit with clutch and motor will be seen under Clutches, in Figs. 251, 252, and 254.

Amidships Alone or with Clutch. The amidships unit joined with the clutch, shown in Fig. 253, represents the Winton transmission and clutch. This is not a common construction on pleasure cars, although it is used on quite a number of trucks. On the amidships-clutch unit type, however, the combination is not quite so intimate as the one in which the two units are enclosed in a common case.

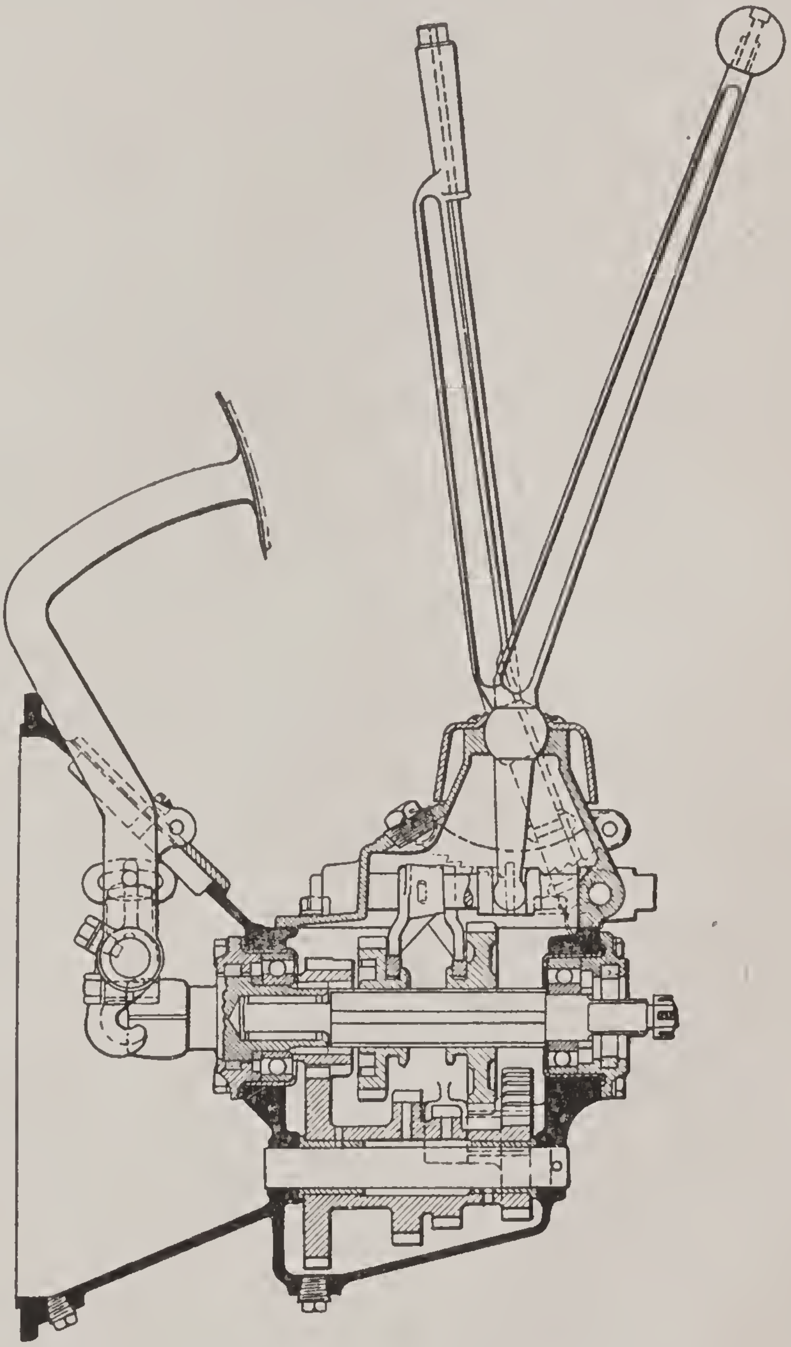


Fig. 274. Gear Box Used in Hackett Cars Is Very Small and Compact
Courtesy of Hackett Motor Car Company, Jackson, Michigan

Amidships Joined with Driving Shaft. The amidships unit joined with the forward end of the driving shaft is well shown by the Locomobile, Figs. 271 and 272. The universal joint with the driving-shaft pivots is seen at the left side of both these views. In this construction, which is more widely used than the other amidships arrangement, there is usually a frame cross-member at the point on which the rear end of the transmission is supported. This same arrangement is used on the Stearns-Knight four-cylinder chassis, the transmission of which is shown in Fig. 276. In this transmission the stiffness of the cross-member at the rear end of the transmission is also utilized to support the brake drum of the foot-brake system.

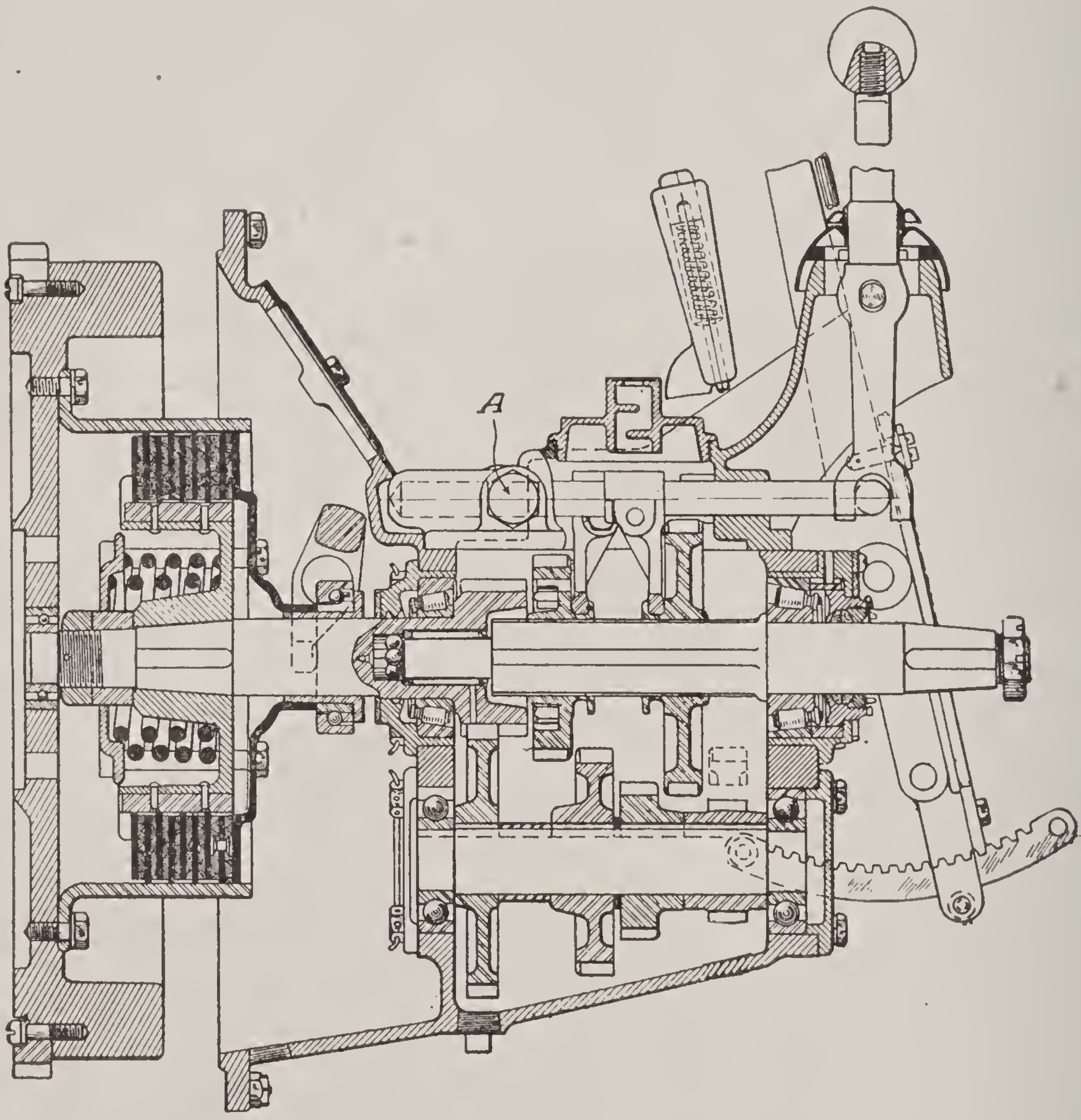


Fig. 275. Gear Box and Clutch of Peerless Eight
Courtesy of Peerless Motor Car Company, Cleveland

The short stiff shafts on the transmission will be noted, also the many splines on the main shaft and the use of double row ball bearings on the main shaft, with a flexible roller on the spigot, and the same type of bearings on either end of the layshaft, which is alongside of the main shaft. Note also the means provided for adjusting the countershaft longitudinally by the two steel screws projecting through the bearing caps so that this adjustment can be made from the outside.

Rear Unit with Rear Axle. The position at the rear axle is not as widely used as a couple of years ago, but those manufacturers using it have large outputs, so that a considerable number of these cars are in use and considerably more are being added each year. One of these, the Studebaker, is shown in Fig. 277. This is a shadow drawing of the rear axle and transmission, showing the upper, or main, shaft of the transmission in full and the layshaft which is below it, partially. As will be noted, this position of the transmission calls for two operating rods, each the full length from the operating levers to the rear axle. The rod on the left operates the reverse and first speeds and that on the right second and third, or high, speeds.

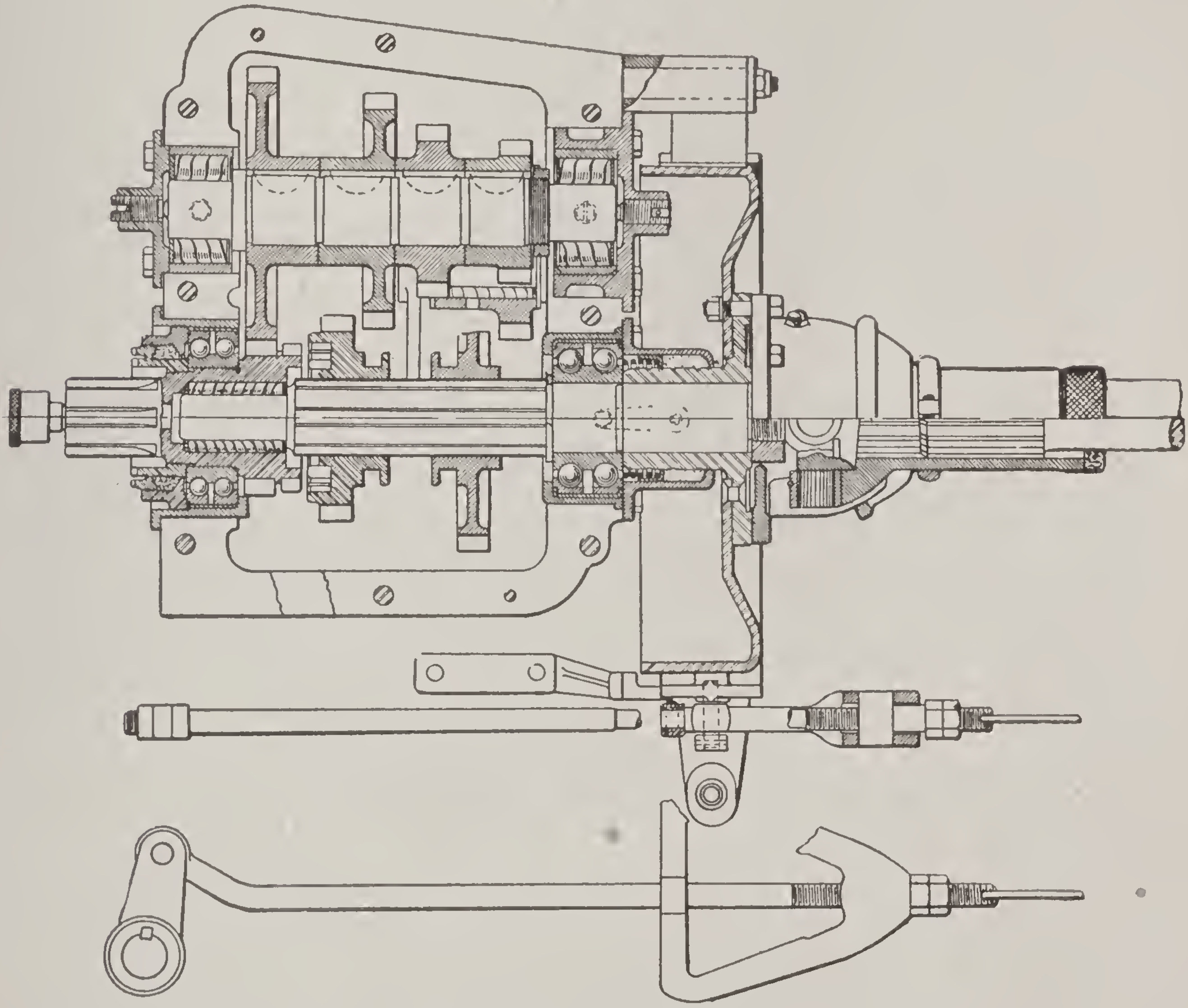


Fig. 276. Three-Speed Transmission and Brake of Stearns Four-Cylinder Car
Courtesy of F. B. Stearns Company, Cleveland, Ohio

To make this shifting of gears and connection of levers with the actual position of the gears plain, Fig. 278 is also shown. In this figure the gear-shifting lever is placed in the center and is shown solid in the neutral position and lighter in the other four positions.

Just below it, the transmission is shown with the position of the gears for neutral, while in the four corners, corresponding to the four positions of the lever, the positions of the gears when the lever is in each one of the positions are shown. These positions indicate that there is a driving gear and two sliding members on the main shaft and four gears on the layshaft. At the left in the picture, the gear toward the rear is for reverse and another gear (not shown) is needed to complete the reversal of motion. When the lever is swung to the left and forward, this group is completed and reverse speed results.

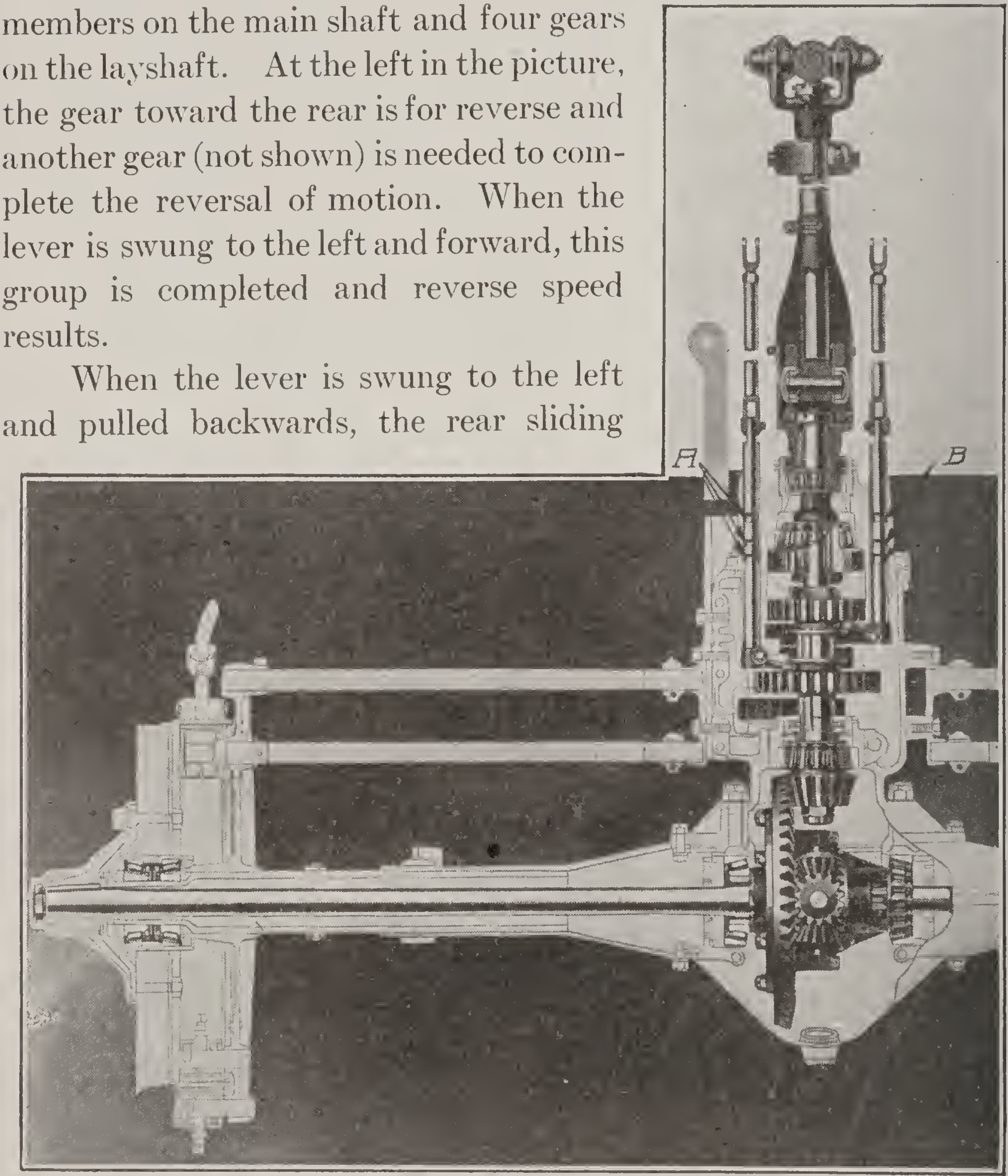


Fig. 277. Studebaker Transmission Combined with Rear Axle
Courtesy of Studebaker Corporation, Detroit, Michigan

When the lever is swung to the left and pulled backwards, the rear sliding member is moved forward to mesh with the second gear on the layshaft, as shown in the diagram at the lower left-hand corner, and first, or low, speed results. With this gear in its neutral position—as it is left when the shifting lever is swung through the neutral position and over to the right—a further movement to the front picks up the forward sliding gear and moves it back into mesh with the third gear on the layshaft; this combination, as shown in the upper right-hand corner, gives second speed. When the lever is moved back, it moves the gear forward, giving high speed and direct drive, as shown at the lower right-hand corner.

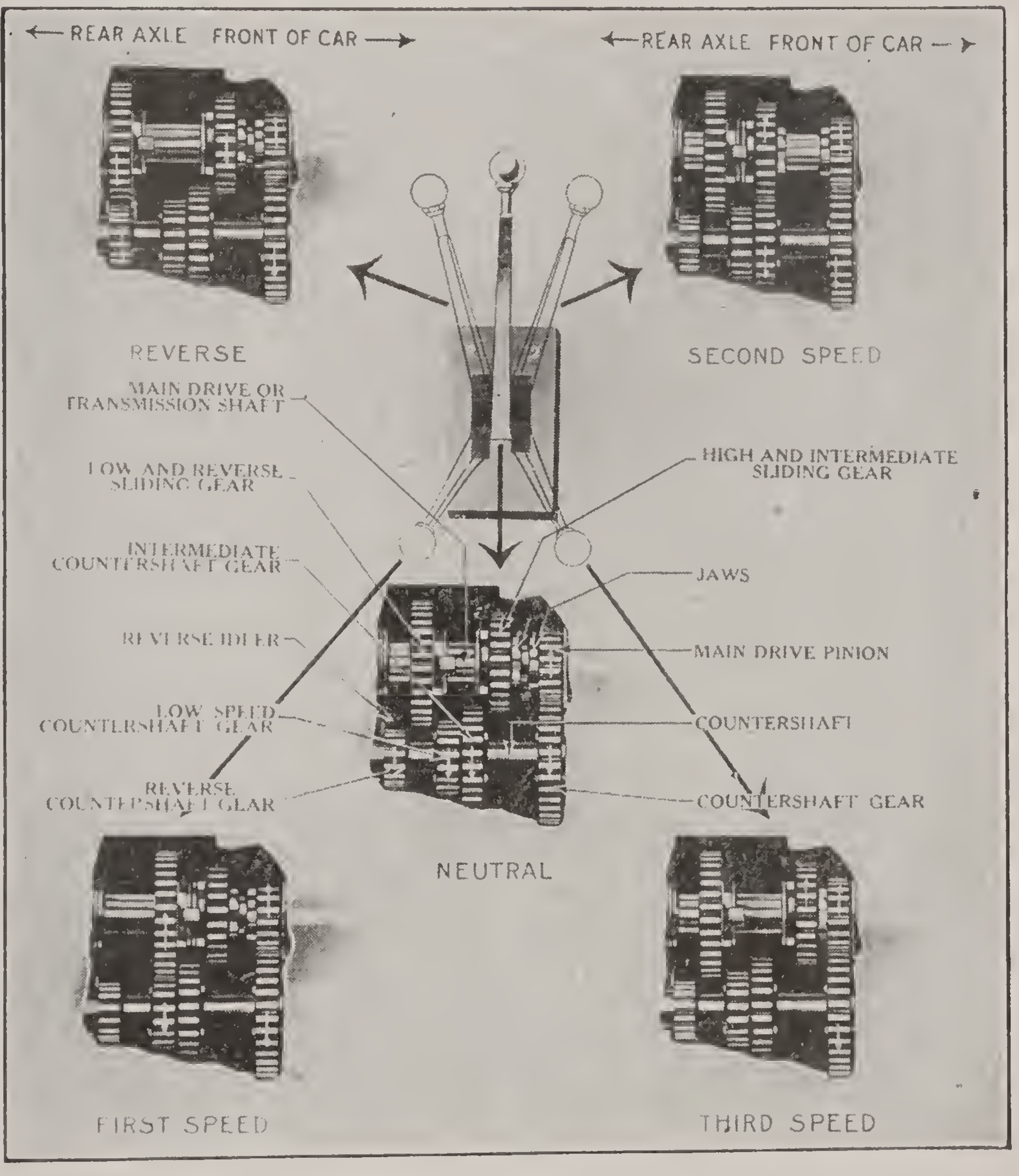

← REAR AXLE FRONT OF CAR →
← REAR AXLE FRONT OF CAR →
REVERSE
SECOND SPEED
MAIN DRIVE OR TRANSMISSION SHAFT
LOW AND REVERSE SLIDING GEAR
HIGH AND INTERMEDIATE SLIDING GEAR
INTERMEDIATE COUNTERSHAFT GEAR
JAWS
REVERSE IDLER
MAIN DRIVE PINION
LOW SPEED COUNTERSHAFT GEAR
COUNTERSHAFT
REVERSE COUNTERSHAFT GEAR
COUNTERSHAFT GEAR
NEUTRAL
FIRST SPEED
THIRD SPEED

Fig. 278. Diagrams Showing Working of Studebaker Transmission

Interlocking Devices. Nearly all transmissions have a form of stop lock on the shifting rods in the transmission, which holds the gears in mesh as soon as they have been moved by the operator until he moves them again. In reality this arrangement simply prevents the gears from jumping out of mesh. Generally, the most simple arrangement which will hold the gears is used. In the ordinary form this arrangement consists of hardened steel wedges with light springs back of them and deep grooves in the shifting rods into which these wedges fit.

In Figs. 271 and 272, the notches in the shifting rods can be seen plainly. In Fig. 275, the bolt head *A* indicates the location of one of the shifting locks. In Fig. 277, *A* shows the notches in the low and reverse rod and *B* those on the second and high-speed shifting rod.

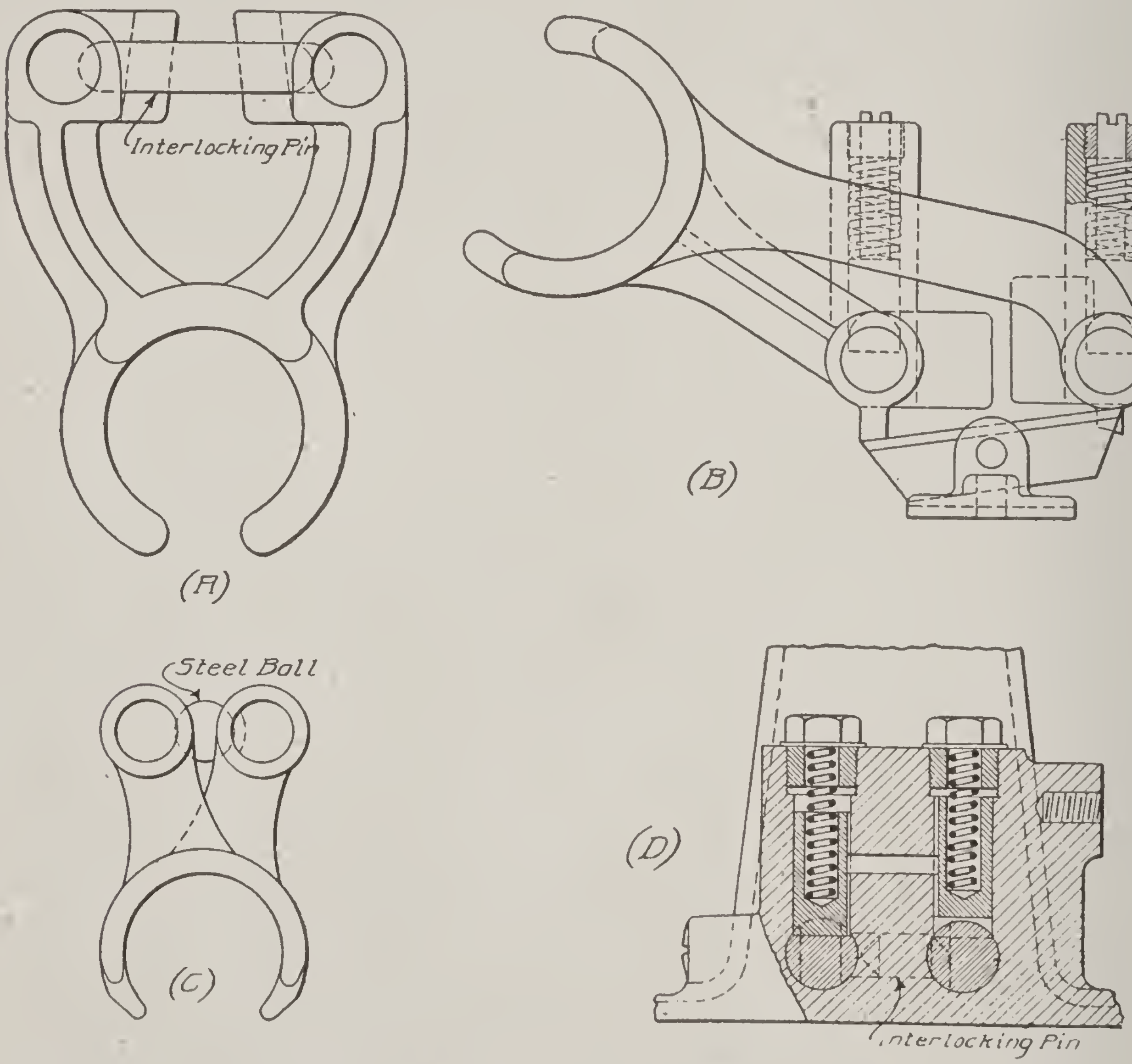


Fig. 279. Various Forms of Transmission Interlocks

Not all transmissions have the wedge and notch, as Fig. 279 indicates. This figure shows: at *A*, a method of interlocking by means of a pin at the shifting forks (not rods) which project into shallow holes in the two shifters; at *B*, a rocking, or tilting, bar beneath the shifting forks, which is pressed into a notch in either fork when moved from neutral; and at *C*, the use of a steel ball—all three arrangements being used by the American Die and Tool Company. The form at *D* shows the pin used by Grant-Lee Gear

Company, the grooves in the rods being deep enough to accommodate this form in a neutral position so that the rod can be started. But the guide hole in the central housing in which the pin is moved across by the motion of one rod, owing to the shape of the bottom of the groove, prevents the other rod from moving.

Electrically Operated Gears. In substance, the electrically operated transmission has all the hand levers, rods, and other levers replaced by a series of push buttons. When it is desired to change speeds, even before the actual change is necessary, the driver presses the button marked for the speed he thinks he will require. Then, when the actual need becomes apparent, he throws out the clutch and immediately drops it back again, all this forming but a single forward and back movement of the foot. During the slight interval while the clutch is out, the electrical connections shift the gears automatically, so that when the clutch is let back, the gears are meshed ready to drive.

Principle of Action. To explain this action briefly, the gears are moved by means of solenoid magnets, which are nothing more than coils of wire, through which an electric current from a convenient battery is allowed to pass. Through the center of each one of these coils passes an iron bar. When a current passes through the coil, it is converted into an electromagnet and draws the iron bar inward. As the other end of the bar is connected to the gear to be shifted, this movement of the bar shifts the gear. Consequently, when the button is pressed so that current flows through one of the coils, that action shifts the gear for which the button is marked.

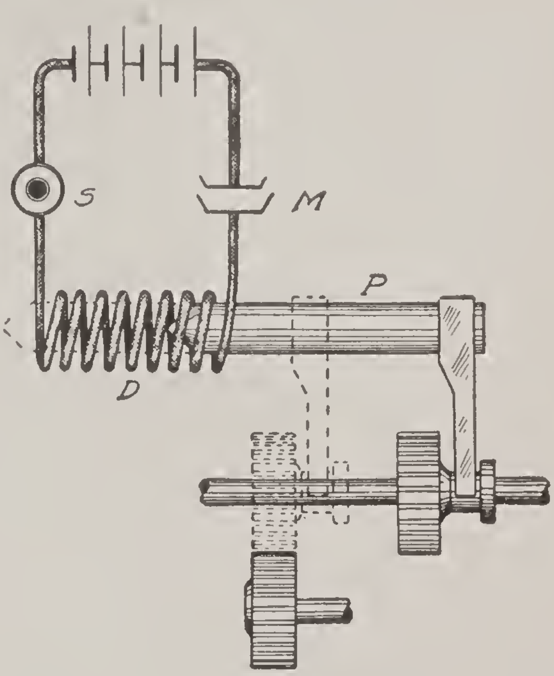


Fig. 280. Sketch Showing How a Solenoid Moves a Gear When Current Flows

By referring to Fig. 280, this action will be made more clear. The diagram shows but one pair of gears to be meshed, and the battery, push button *S*, coil *D*, iron bar *P*, and clutch connection *M* are all shown as simply as possible. When button *S* is pressed, current through the coil *D* will draw the bar *P* and mesh the gears as soon as the clutch has been thrown out, thereby closing the circuit at *M*. The application of this to an actual transmission is shown more in detail in Fig. 281, which shows the clutch pedal and its connection to the six solenoids necessary to produce four forward speeds, one reverse speed, and a neutral point.

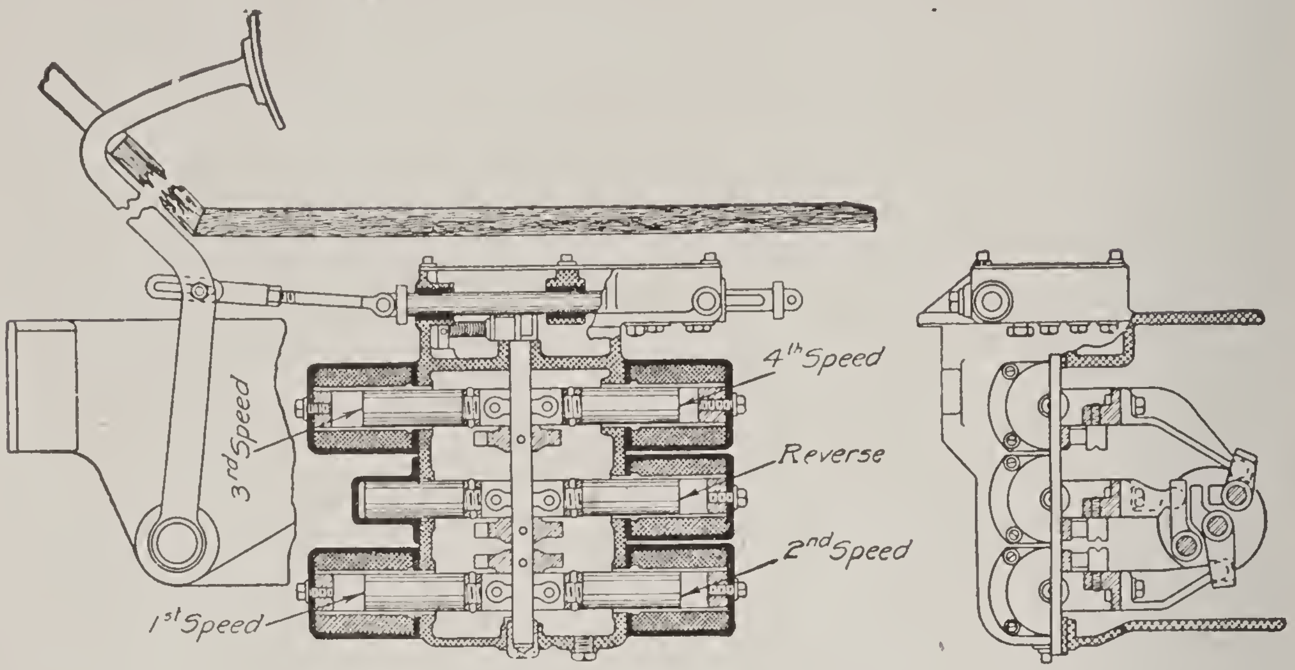


Fig. 281. Arrangement of the Solenoids and Pedal in the C-H Electric Gear Shift

On the steering wheel, Fig. 282, the control group of six buttons will be noted on the small round plate at the center, with the addition of the horn button in the center. In Fig. 283 is another arrangement.

In the 1916 forms of electric-control systems, the buttons are grouped in one instance on the top of a small box four or five inches square, which is placed on the steering post below the wheel; in another, on the dash; and in a third, on a rod connecting post and dash.

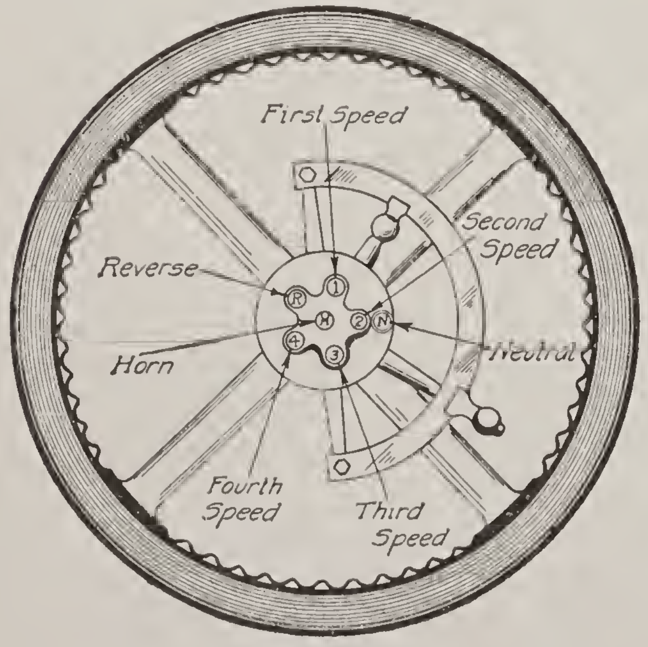


Fig. 282. Arrangement of Buttons for Gear Shifting

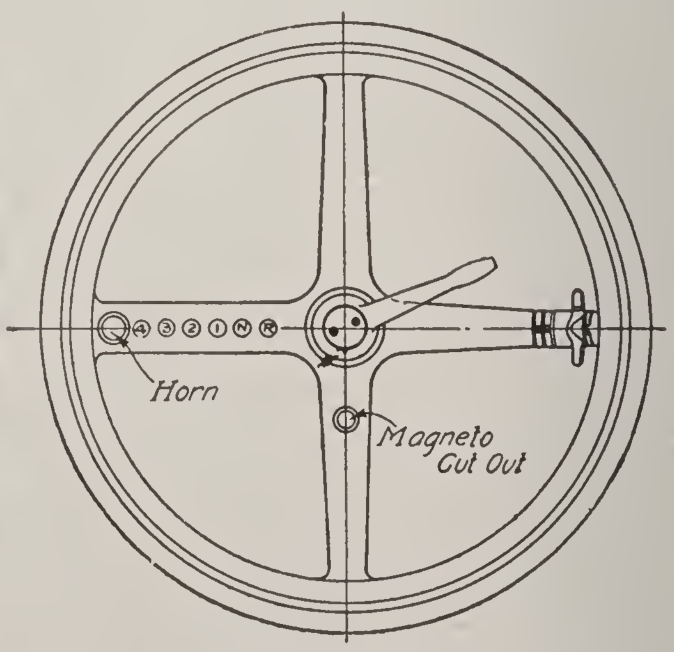


Fig. 283. Another Arrangement of Buttons for Gear Shifting

Pneumatic Shifting System. The pneumatic system of gear shifting is along lines somewhat similar to the electric system, air under pressure being used to move the gears instead of a hand lever and rod combination. For this purpose it is necessary to add an air compressor, a tank to carry the compressed air, and what is called the "shift"—really a complicated valve and a series of plungers—to the car. The valve and plungers respond to a finger lever on the steering wheel, the same as the electric system responds to the buttons. Air is admitted behind the plungers, which moves the gears as soon as the clutch is depressed. It is seen, therefore, that this system, like the electric shifter, permits the anticipation of the needs of the car.

Railway Car Needs. All transmissions previously presented have had but one reverse. For gasoline railway cars, the inability to turn the car requires as many reverse speeds as forward, which means special gearing. Usually, this gearing is accomplished by means of a pair of bevels, each with a clutch, meshing with a single driving bevel. Obviously the two driven bevels will turn in different directions, and each will drive when its clutch is engaged. By shifting the clutch to the one which gives a forward speed, all the speeds of the gear box become forward speeds; by shifting to the one which gives reverse, all the speeds become reverse speeds.

INDIVIDUAL CLUTCH

General Types Used. While the number of adherents to the individual-clutch type of transmission is not as great as that of either the progressive or selective types of sliding gear, it holds its own; and, as time passes, it gains adherents. In this form, all the gears are in mesh at all times, and what has been called "the barbarous and unmechanical" method of clashing gears is entirely done away with. The individual-clutch type is operated on the selective plan but otherwise has nothing in common with the latter.

The forms of clutches used vary greatly, as might be expected. The following are in use today: jaw clutches (both two- and multiple-jaw); internal-external gears, multiple disc, cone, and friction clutches other than the multiple-disc form.

Using Internal Dogs. One type in which the gears are engaged by internal dogs—the gears being in mesh at all times—has four sets of gears, those on the main shaft being keyed or otherwise fixed to the shaft, while the gears on the jackshaft run idle except when the gear-shifting lever is moved forward to an engaging position, which throws an internal dog up into a slot inside the gear. This position makes the gear one with the shaft, and the power is transmitted directly. The dogs in the latest form of this transmission take the form of hardened and ground steel balls.

Disc Type. Many of the early individual clutch types of transmissions used discs, each gear having its own set and each set having sufficient surface to carry the whole power of the motor. While bulky, this had undeniable advantages, for it allowed starting on any gear.

Contracting-Band Type. While advocates of discs are numerous, other devices do not lack friends. Fig. 284 shows a form on the Haynes-Apperson cars that attained much popularity. In it the clutching action is produced by means of contracting bands working on large diameter drums, the drums being keyed each to its own gear. The full explanation of the action is as follows: The engine drives the shaft *A*, upon which are mounted the gears *C*, *D*, *E*, and *F*. These are all permanently fixed to the shaft and rotate with it. Upon the driven shaft *B* are mounted an equal number of gears meshing with the former, but all loose upon the shaft so as to spin idly. Bolted to each of the latter gears is a large drum, while close to it is a framing upon which is mounted a contracting band. The latter framing is keyed to the shaft, so that when it is rotated the shaft must turn with it. In action, then, when any speed was desired, the band was contracted until it seized the drum bolted to the gear which gave that speed; thereupon, the gear, drum band, and framing all turned as a single piece.

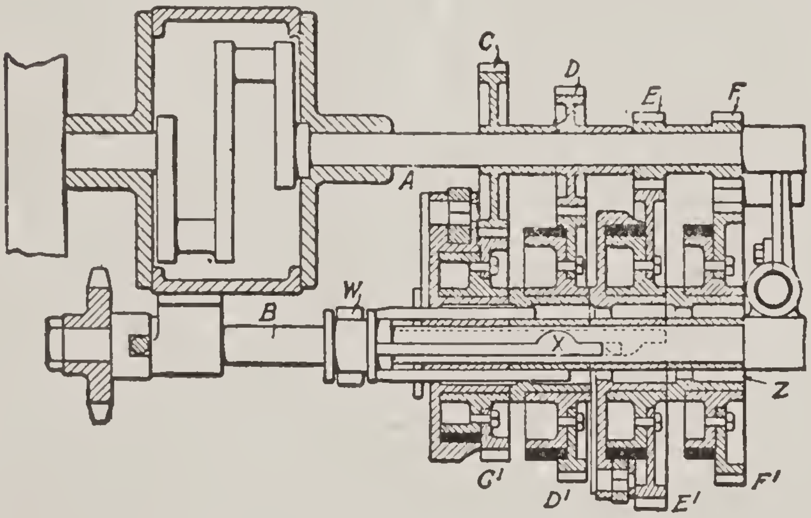


Fig. 284. Early Form of Haynes Clutch Gearset

Single-Disc Winton. Winton long advocated the individual clutch gear, his clutch taking the form of a single disc pressed against the gear by means of numerous fingers, Fig. 285. A conical sliding piece *G* or *J* expanded the fingers pivoted on *M* and *H* so that they pressed against the disc within the gears *D*, *K*, or *N*.

Internal-External Gear Type. Many of the gears already given date back several years, but the gear illustrated in Fig. 286 is more modern, and is being used today by the International Motor Company of New York City and of Allentown, Pennsylvania.

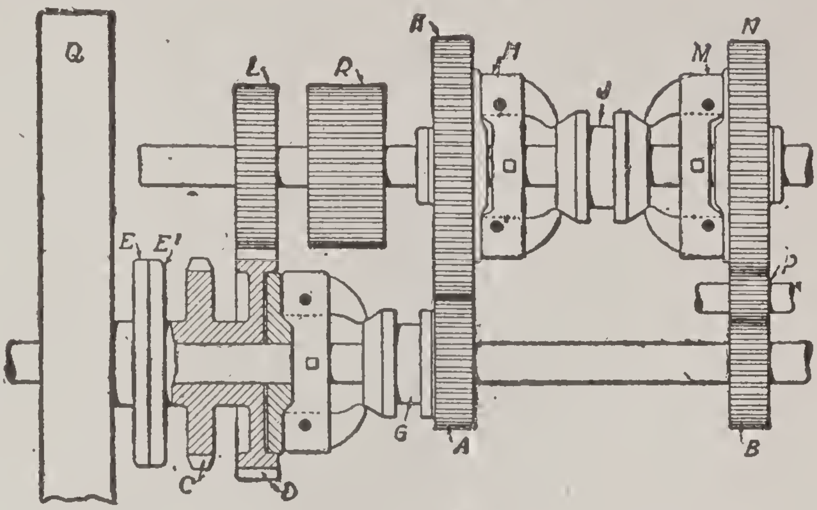


Fig. 285. Early Form of Winton Individual Clutch Transmission

The principle upon which this gear works, as shown by Fig. 286, is that of the internal-external gear. The gears which transmit the power are always in mesh. Each one of these is bushed and runs idly upon the main shaft. Contained within each gear and an integral part of it is an internal gear of twenty-four teeth. Sliding on the squared shaft are four 24-tooth gears; these are specially built for easy engaging with the internally cut gears.

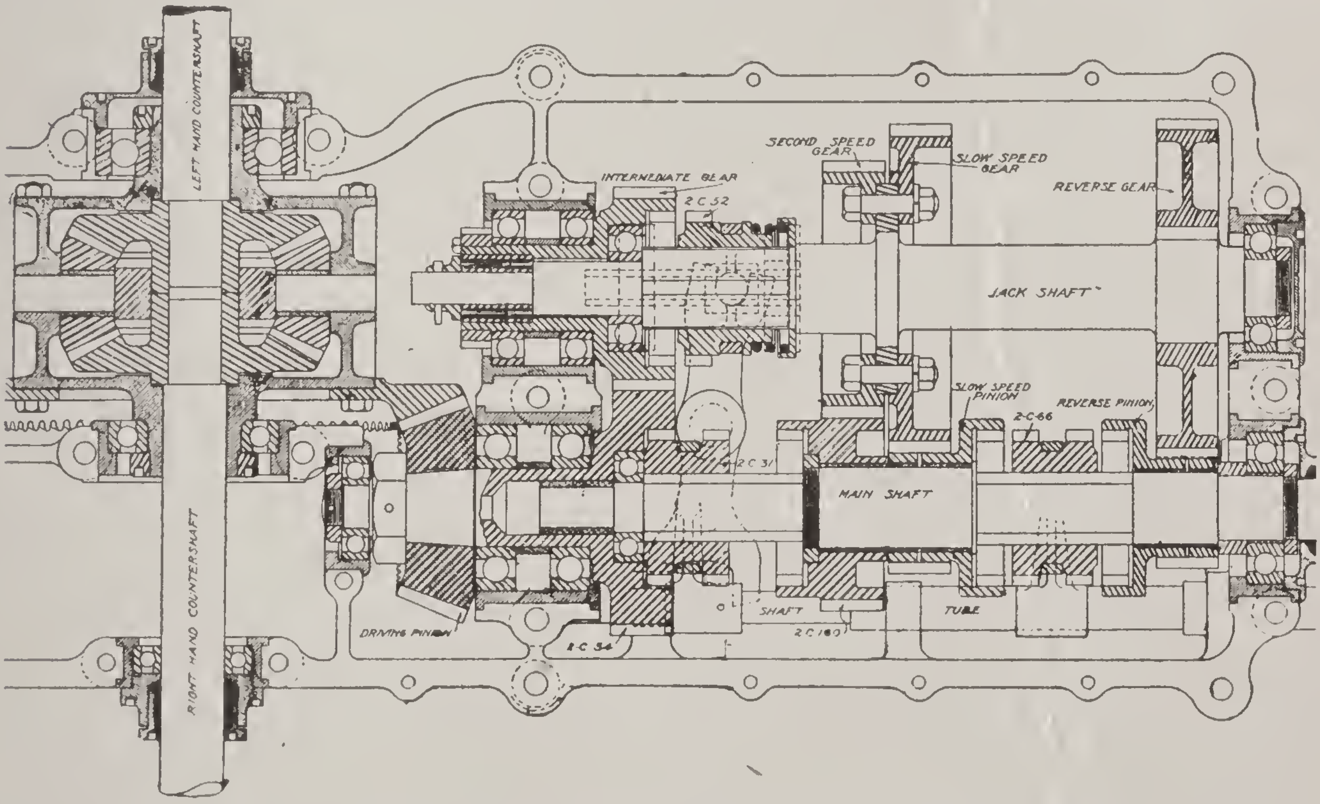


Fig. 286. Mack Commercial Car Individual Clutch Type of Gear Box
Courtesy of International Motor Company, New York City and Allentown, Pennsylvania

To follow the letters placed on the parts of this gear, high speed is obtained by sliding the piece *2–C–31* forward into gear *2–C–34;* this action swings the piece, shown dotted beneath, so as to throw out the clutch on the lay shaft *2–C–52.* On high speed, the two gears locked together are the only ones to turn, all others being idle. The same piece *2-C-31,* when slid to the right, meshes with the internal gear of the second-speed pinion *2–C–160.* This sliding member slides upon a squared shaft, so the drive is positive. The action of the first, or slow speed, and reverse are the same as those just described, being produced by the shifting of the clutch member *2–C–66.* Attention is called to the ball bearings used on this transmission, which are remarkable only when it is remembered that this is a commercial truck transmission. Students of automobile construction will find many interesting constructional details in this illustration, which is a reproduction of the manufacturer's working drawing.

Still another similar form uses three cone clutches in the transmission, that for the high speed being augmented by a set of pins, or dogs, which, as the clutch gradually takes hold, slip into an equal number of holes in the driven gear. In this way, the two are made as one, which makes slipping impossible—a very important feature.

Transmission Operation. As has been pointed out previously, practically all transmissions operate all gears by means of a long hand lever, placed either at the side of the car or in the center, according to the location of the control. Even on planetary forms, still to be described, at least one of the various speeds is controlled by a hand lever. The electric- and air-shifting methods have made a start, and a good one, but until their number increases materially, these types can be considered as only having started their development.

Transmission Lubrication. A fairly heavy lubricant is generally recommended for gear-box use—either a special form of about the right consistency, or else a home-made mixture of about half-and-half of light oil and hard grease. Some firms recommend a graphite grease. The lower part of the case should be filled to a point, or level, where the largest gears dip continuously. This will insure a constant agitation of the lubricant, which will thus get to all moving parts and surfaces. Having the lubricant too stiff is bad, because then the gears simply cut a path through it without moving the rest. This results in all other parts running practically dry. Too thin a lubricant or too much of it will make a fairly heavy drag on the motor, which loss of power should be avoided. Gear-box lubricant generally is introduced in bulk by the removal of the cover, usually of a large size to allow of this. The outside parts carry their own grease and on cups.

Transmission Bearings. By looking back at the various transmissions shown, it will be noted that ball bearings are used most freely. Roller bearings in various forms are coming into use, as the shorter series produced in the last couple of years has shown designers that thist ype would produce a compact gear box, their size having previously limited their use. Plain bearings are not used at all on good cars.

Transmission Adjustments. Few adjustments are needed in the modern gear box. However, provision for wear is made in the operating rods and levers, both within the case and without. In some cases the shafts may be slightly shifted endwise to secure better meshing of the gears after wear. Bearings, too, are arranged to shift slightly in an endwise direction to take care of wear in other parts and not so much in the bearings themselves.

PLANETARY GEARS

Method of Action. The planetary, or epicyclic, form of gearing offers many advantages, but, strange to say, the American people, although inclined toward simplicity and cheapness in combination, will not have it in this form, and, as a consequence, this excellent gear-reducing means is fast losing favor. The principle upon which all planetaries work is as follows: Connected to the engine is the first gear of the train. The second is one of a series of several gears; these are pivoted in a drum, which may be held stationary by a brake band. The middle, or third, gear in the train, as well as the last, or fourth, is connected to another gear, *a driven gear, not a driver*. Considering but a single rotating train—there usually are three or more—the last-named gears form the fifth and sixth in the whole train. Gears two, three, and four have different numbers of teeth, as well as gears one, five, and six. Holding the band which holds the drum to which the gears are pivoted, allows each of them to rotate around its own axis, but not around the main shaft. This form of rotation gives one gear reduction.

Another band holds another gear stationary and allows the three-gear unit to rotate around the main shaft as an axis; at the same time it leaves them free to also rotate around their own axis. This produces *another* gear reduction. Another form which is popular in so far as planetary gears are popular is that in which internal gears are substituted for one set of the planets, from which the device obtained its name. This does not complicate the device any; in fact, the only way in which it makes any change is in the manufacturing cost of the gear, internals costing more than spur gears.

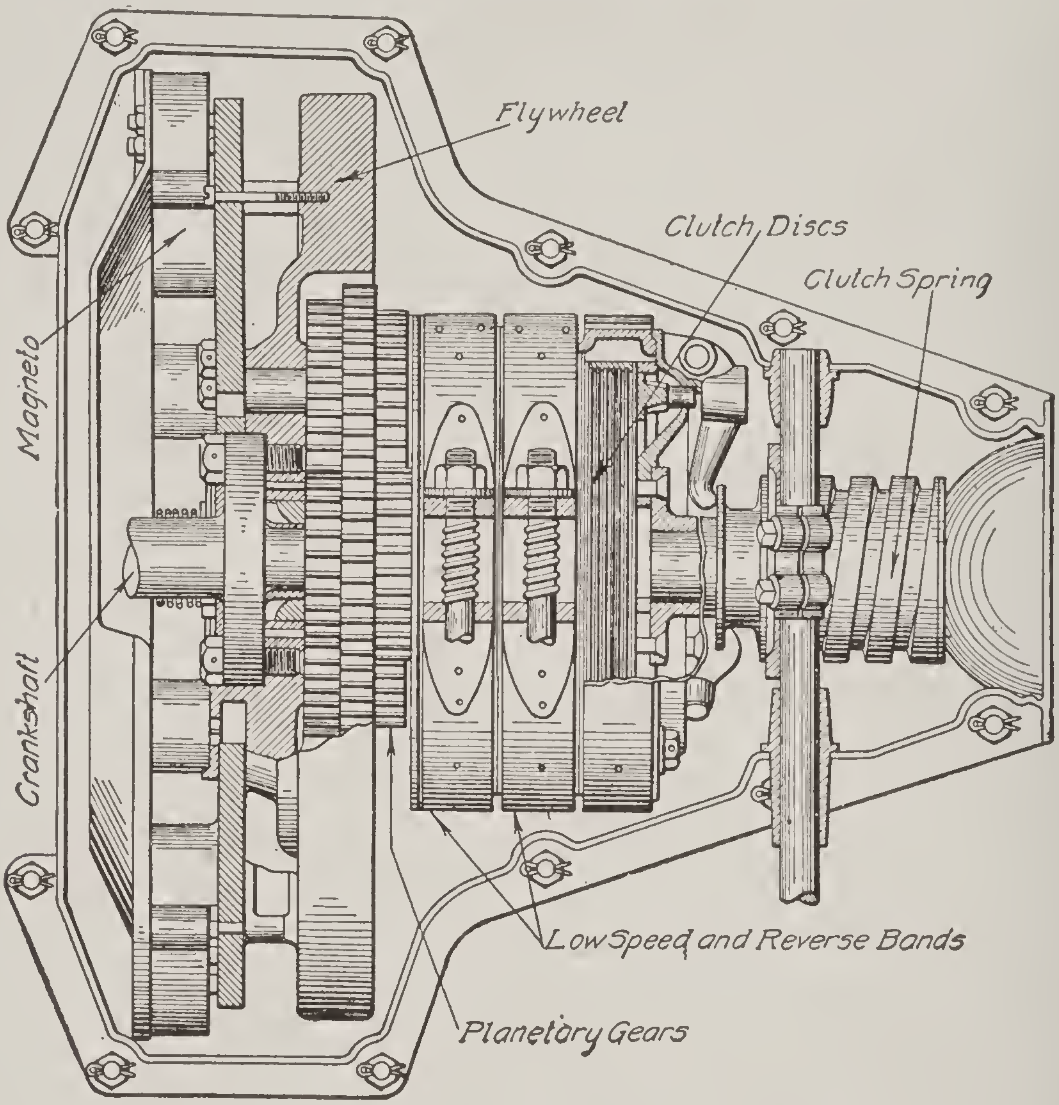


Fig. 287. Drawing Showing Ford Planetary Transmission

Ford Planetary Type. Ford has been a consistent user of the planetary gear; in fact, the simplicity and ease of operation of his well-known and widely used car is largely due to this use. The Ford transmission, which is of the all-spur-gear type, is shown in Fig. 287. This is operated by means of two pedals and a lever, one pedal working high and low speeds, while the other pedal controls the reverse. The first-named pedal, however, must be used in conjunction with the forward movement of the hand lever which locks the high-speed clutch, seen in this figure at the right.

FRICTION DISC

Undoubtedly, when simplicity is sought regardless of cost, the friction drive is the drive used. The cost with this form is not one of money, but rather of other things which must be sacrificed if friction drive is used.

Spur Type. In the interest of simplicity, it may be said that the friction form of drive dispenses with the clutch, being of itself both clutch and change-speed gear. The usual form which this takes is the single spur wheel contacting with another flat-face wheel. Since these must be at right angles, the car is nearly always chain driven, the driving wheel being on the rear end of the crankshaft, and the driven shaft across the middle of the car. To secure a more certain drive and at the same time obtain the differential action, the cross-shaft, mounted upon two independent shafts, is often fitted with a pair of wheels, contacting with opposite sides of the driver. As this method causes the two driven shafts to turn in opposite directions, a gear is necessary at the end of one of them.

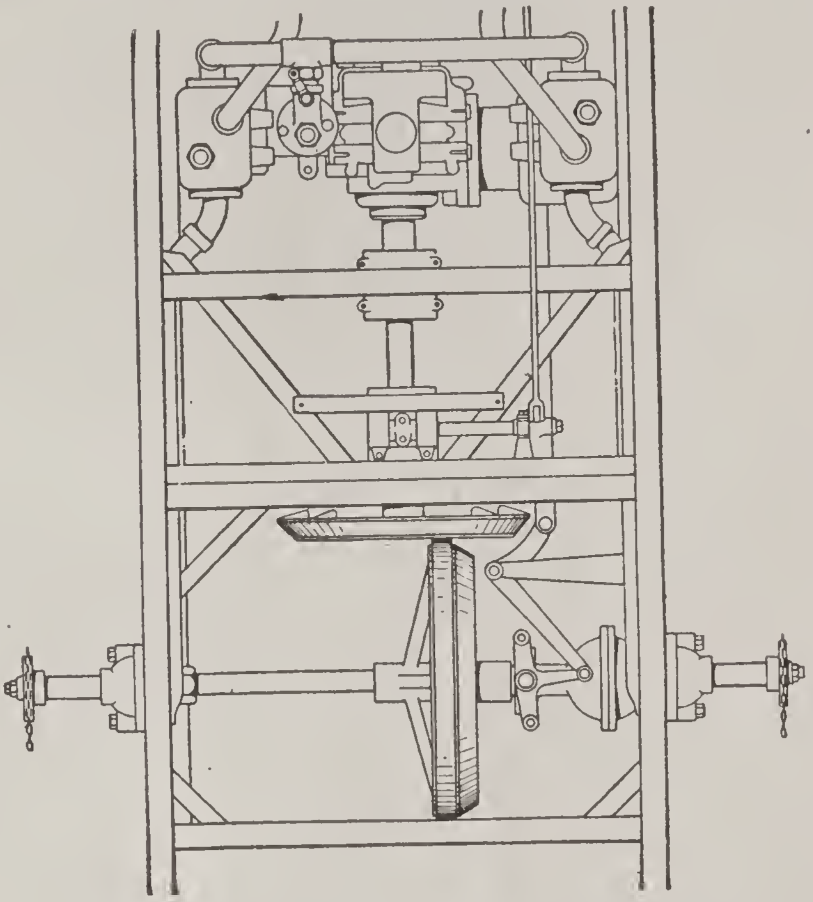


Fig. 288. Friction Transmission with Bevels

The greatest feature of the friction drive is the multiplicity of speeds obtainable, these being infinite in number, since every different position of the driven wheel on the driver results in a different ratio and, consequently, a different speed. To obtain these various changes, the wheel which meets the other edge-on is usually arranged to be advanced up to and withdrawn from the wheel presenting the flat surface. In action, a motion of translation is given to the wheel at the same time as the motion up to or away from the surface. This motion of translation changes its position and consequently its speed.

Over the three-wheel arrangement, the use of the four-wheel arrangement possesses some undeniable advantages, particularly if the two parallel driving wheels are arranged to drive the others in pairs. This arrangement makes the direction of rotation of the wheels alike, and no intermediate gear to change the direction of one shaft is needed. A simplification of this form utilizes the flywheel of the engine as the forward driving disc.

Bevel Type. Bevels have many advantages over spur friction wheels. They are found in combinations, such as a single pair of bevels or three bevels, and in multiple combinations, without limit to the number of bevels. Fig. 288 shows the use of a single pair, but in combination with a flat face on one and a spur attached to the other; this makes the whole consist of four wheels in reality.

Another combination sometimes used is that of three bevels. One of the bevels has a flat face and a spur, making really five wheels. The spur wheel in every case takes the final drive. A direct drive on the high gear is obtained by the use of a cone clutch on this spur and another clutch with which it engages on the driving wheel. One bevel gives forward speeds, and through the other the various reverses are gained. The friction drive, although theoretically the simplest and most ideal form of drive, is not very popular.

MISCELLANEOUS TYPES

Freak Drives. What are termed the freak drives attract much attention from inventors, but little from hard-headed constructors. Thus, the belt drive was once advanced as *the* simple drive, yet it made no progress. Today there are few belt drives used in final driving in America, although a few are still made in Europe. There is a low-price French car, Fouillaron, with this drive; and a single-cylinder Italian car, the Otav, selling for the equivalent of $150, which is also equipped with a belt drive.

Cable and Rope Drives. When cycle cars were first brought out and by many considered as destined to replace both the low-priced cars, on account of their still lower price and simplicity; and motorcycles, because of their greater comfort, superior appearance, and greater carrying capacity, many of the simple drives were revived and applied to the cycle cars. The types used include the cable drive, which attracted much attention at one time in the motorbuggy field, the rope drive, the flat belt, the V-belt, the cloth-covered chain, and many others. With the collapse of the cycle-car boom, these went out of use.

Hydraulic Gear. *Janney-Williams.* The hydraulic transmission has been advanced as a cure for all automobile troubles, representing as it does the elimination of clutch, differential, and the driving mechanism. It consists of a pump to circulate the fluid, and one or two motors, usually attached to the rear wheels and propelled by the fluid. In the Janney-Williams hydraulic gear, which has been successfully used for some time in other fields, but has just recently been tried for automobiles in England, there are three similar pumps, one being used as a pump and the other two as motors. By rotating the driving ring so that it assumes different angular positions, the throw of the small pistons, of which there are nine in all, is varied from zero up to a maximum. Since the action of the fluid in the motors connected to the wheels is opposite to this, it amounts to varying the speed, the number of changes being infinite, as in friction gearing.

Manly. Another hydraulic drive, of equal merit and of American manufacture, is the Manly. This differs from the Janney-Williams only in the form of the motors; the fluid and its use are the same in both cases. This drive has for its object the securing of any desired speed of the driven shaft, either forward or backward, without changing the speed or direction of motion of the driving shaft and of transmitting the power to a shaft, which is either in line with the driving shaft or which lies at any angle to the driving shaft and is separated from it. It consists of a multi-cylinder pump having a variable stroke, which is attached to the driving shaft, and of one or more multi-cylinder motors having a fixed stroke, which are attached to the driven shaft, together with pipe connections, or passages, between them for transmitting the working field. The various cylinders, both of the pump and motors, radiate equidistantly from a central crank chamber, and the pistons or plungers are connected to a single crankpin which is common to all. The fluid used is ordinary machine oil, its lubricating qualities and freedom from the danger of freezing admirably fitting it for such a purpose. When the system is once filled, the oil is used over and over again, being in continuous circulation from pump to motor through one set of pipes, or passages, and back again from motor to pump through another set. The stroke of the pump may be varied at will, but that of the motor is fixed. The variation of the pump stroke is accomplished by a crank, on which an eccentric bushing is mounted. By revolving the bushing with reference to the crank, its center line is brought into alignment with the center of the shaft, and when this position is reached, no reciprocating motion is communicated to the pump plungers. The Manly is constructed under license by the American-La France Fire Engine Company, Elmira, New York, and has proved its worth on very large trucks and on some of their fire apparatus.

In recent years a number of hydraulic transmissions have been brought out, but all these face the fundamental difficulty that when the pump chamber is liquid tight the friction is excessive.

Pneumatic Drive. There has been some talk of a pneumatic drive also, this idea not differing greatly from the previous one of using liquids. In this scheme a large tank of compressed air is provided for the purpose of starting the engine, helping to get up speed quickly, and for use on hills when excess power is needful or at least helpful. If used as planned, it would allow of the elimination of the reverse and would be utilized for braking as well, the present form of band brakes being replaced by air brakes. This is but a prospective scheme, never having been tried; yet in considering the future, it is worth more than a passing thought because of its latent possibilities.

Electric Drive. To speak of an electric drive sounds peculiar, yet that is what should be used for a final drive through the medium of electric motors. This form, spoken of abroad as the *petrol-electric car*, is attaining much headway there. It gains slowly, it is true, but, nevertheless, surely—each year seeing one or more makes added to the already long list of successful cars in this category.

In the petrol-electric cars, the generator is coupled to the engine in the place ordinarily occupied by the flywheel and clutch, and the armature acts as a flywheel. Then the two motors are set on each side, directly in front of the rear wheels, which they drive through the medium of spur gears; the whole is enclosed to keep out dirt, keep in oil, and reduce noise to a minimum.

On the whole, the electric drive is not losing ground, which, in these days of gasoline shaft-driven cars, is perhaps something gained.

In fact, it might be said that the electric drive possesses so many advantages which are worth having, even at a sacrifice, and so few disadvantages that one is safe in figuring that a few more years will see the number of these drives doubled and possibly trebled.

Electric Transmissions. While the drives just discussed might be called electric drives and still be precise, the Owen magnetic car, which is constructed by the Baker, Rauch and Lang Company, makes use of an actual electric transmission, the Entz, at one time used in a Columbia chassis. This is so arranged that all speed changing is done by a small finger lever on the steering wheel, similar to the ordinary spark and throttle levers. The wiring formerly gave seven speeds forward and two reverse, but a later construction will probably give about twice this number.

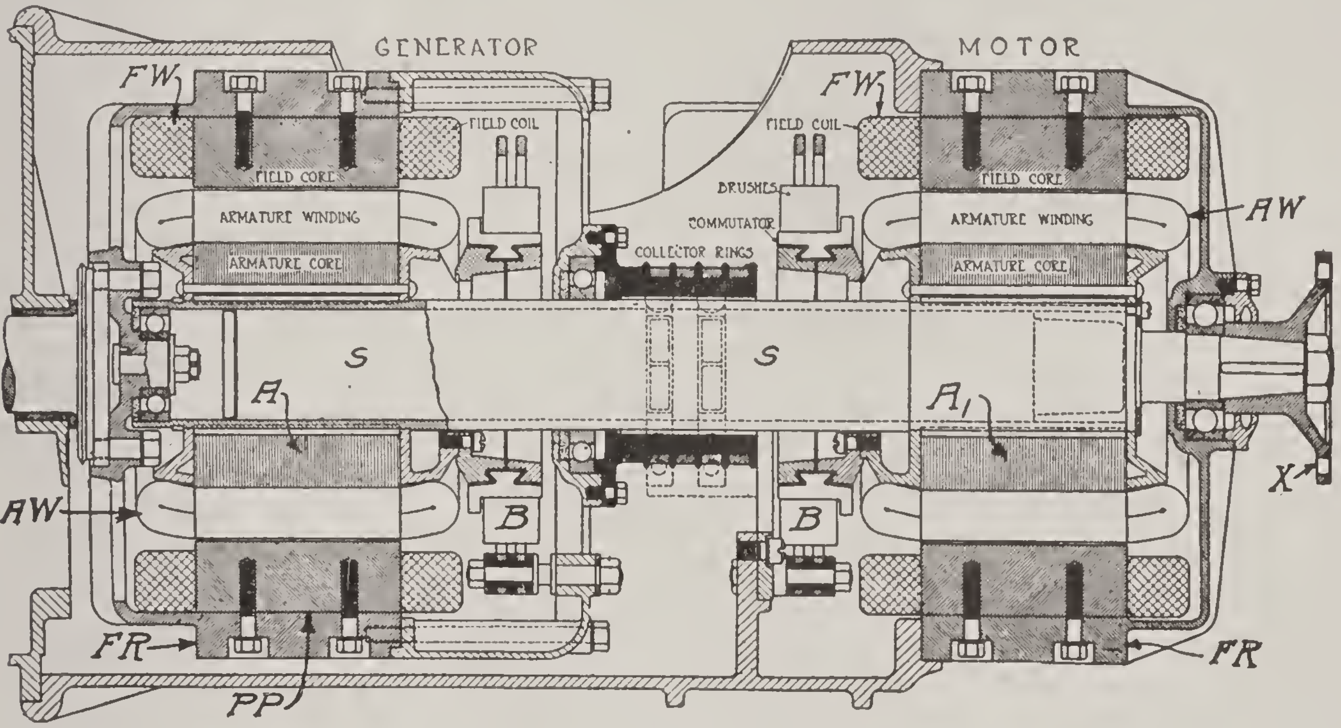


Fig. 289. Drawing Showing Section through Owen Magnetic Transmission

As is shown in Fig. 289, this consists of an electric generator, the field magnet of which is connected to the engine crankshaft and takes the place of the flywheel, the armature being connected with the driving shaft. This transmits the turning effort of the engine by means of the current established in its circuit, due to the speed difference of its members on what constitutes the high speed. Any effort exerted by the engine on one member is transmitted, practically without loss, to the other member, or armature. The clutch-generator member makes a very elastic clutching and transmitting means, but cannot transmit more than the full torque of the engine.

For higher torque, use is made of an electric motor, whose armature is mounted on the driving shaft and receives current from the first, or clutch, generator.

In the figure, the clutch generator is shown at the left, its field part marked *FR,* the field winding *FW*, and the pole pieces *PP*. This portion rotates whenever the crankshaft revolves. Within it is the armature *A* secured to the continuous shaft *S*, which is connected through the joint *X* with the driving shaft to the rear axle.

The second part of the complete system is shown at the right and is practically a duplicate of the clutch generator. Its armature A_1 is carried on the same shaft *S* as armature *A*. Outside this is the usual field part with rings *FR,* windings *FW*, pole pieces, and brushes *B*.

Field *FR* can revolve without any motion of *A*; in fact, it is by varying the relative speed of *FR* and *A* that the different speeds are obtained. For instance, on direct drive the generator is short-circuited on itself and carries armature *A* with it. Then, except for a slippage of 4 per cent or less, between the field *FR* and the armature *A*, the wheels would be driven as fast as the latter rotated. Lower speeds are produced by making the slippage greater. Speed changing, as well as starting and braking, are accomplished by means of the finger lever on the steering wheel. The storage battery is charged at a 10-ampere rate.

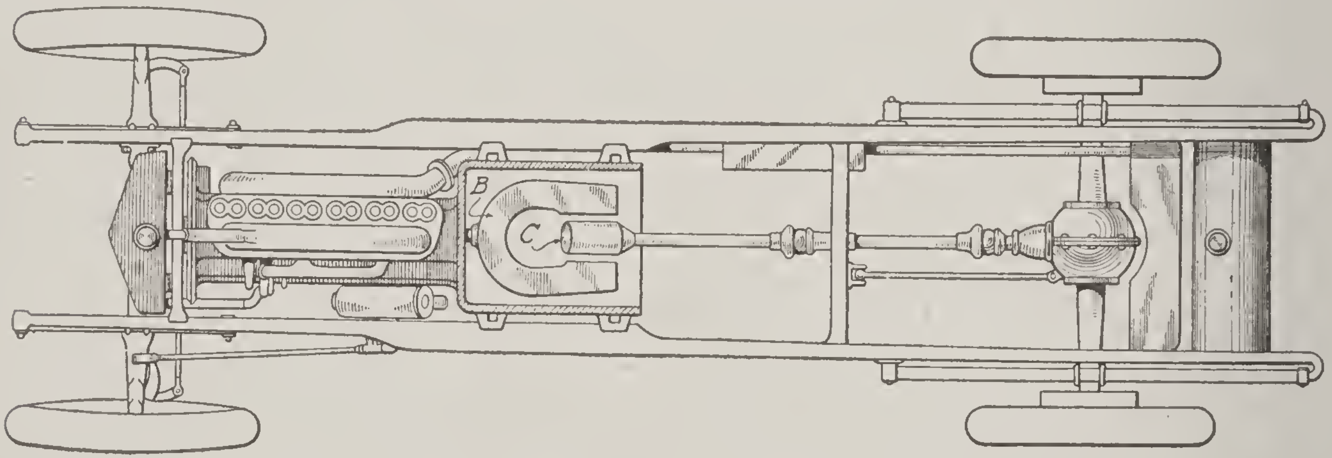


Fig. 290. Sketch to Explain Working of Magnetic Transmission
Courtesy of Baker-R & L Company, Cleveland, Ohio

Perhaps the explanation which follows will give a better idea to the repair man than the foregoing, which is slightly technical The rotating field of the generator, marked *FW*, is comparable to a horseshoe-shaped magnet *B*, Fig. 290, also rotated by the engine. The armature *A* at the left-hand, or engine, end of the shaft is comparable to the piece of steel *C*, which is free to rotate and which will do so when the field rotates and attracts it. If this were connected directly to the driving shaft, as Fig. 290 shows the combination would become a simple electromagnetic clutch and the car would have but one speed. On the level, one speed would be satisfactory, but in deep sand, on a heavy grade, or for any other severe pull, the air space between the rotating field and the armature would bring about the stalling of the engine.

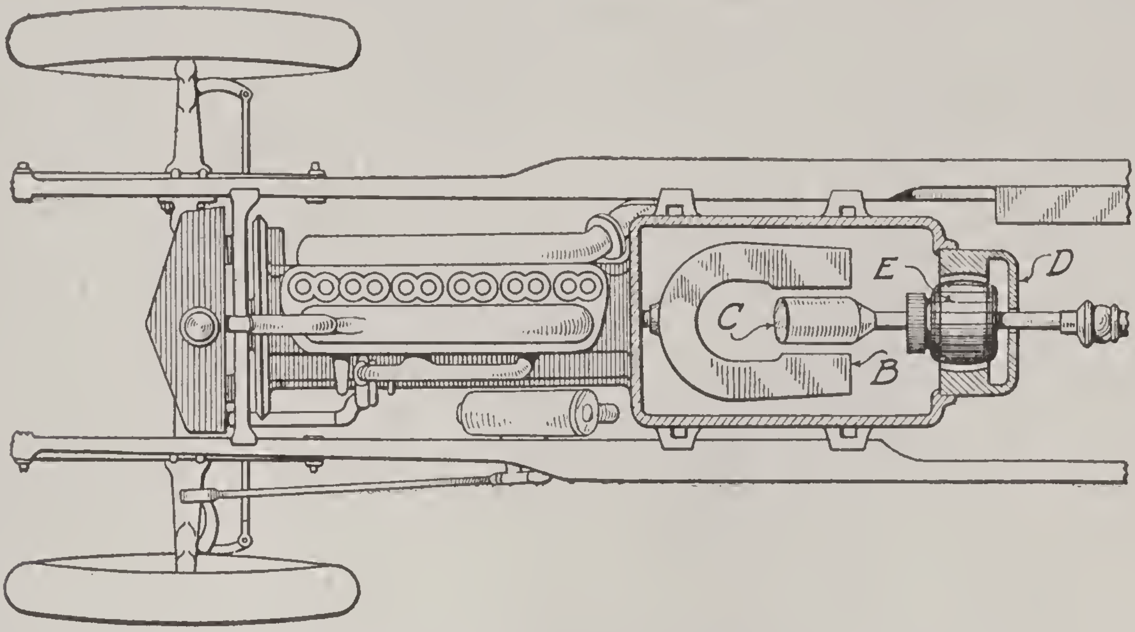


Fig. 291. Second Step in the Magnetic Transmission Explanation

If we add a conventional electric motor just back of *C*, with its field fixed, or stationary, as at *D*, and its armature free to rotate with the armature shaft to which it is attached, about as shown in Fig. 291, *C* will not rotate as fast as *B* when meeting a stiff pull, although it will try to do so. A wire connects the commutator of *C* with the field coils *D*, and the electricity generated by the rotation of *B* relative to *C*, that is, the amount of slippage due to the air gap, is led through this wire to *D* where it acts as power, rotating *E* faster and thus acting as a booster on the propeller shaft.

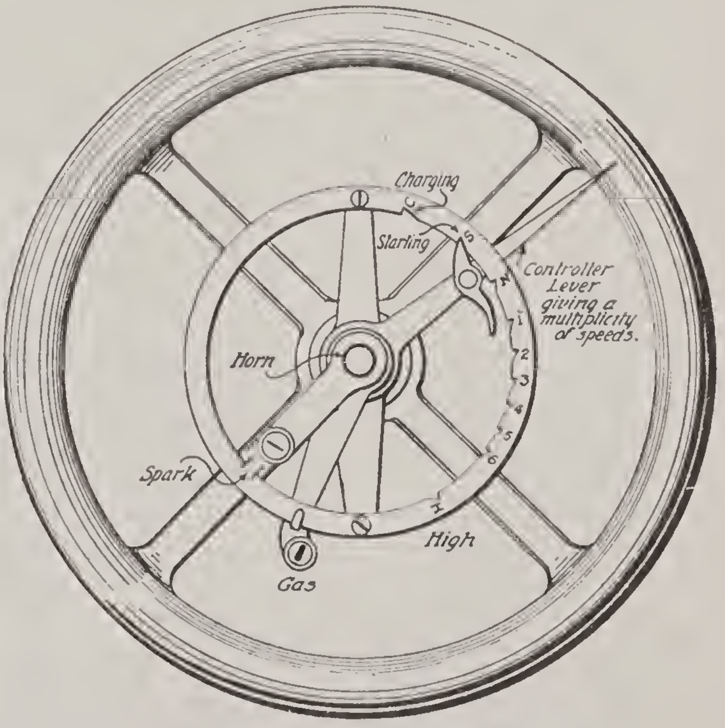


Fig. 292. Steering Wheel Quadrant of Owen Magnetic Car

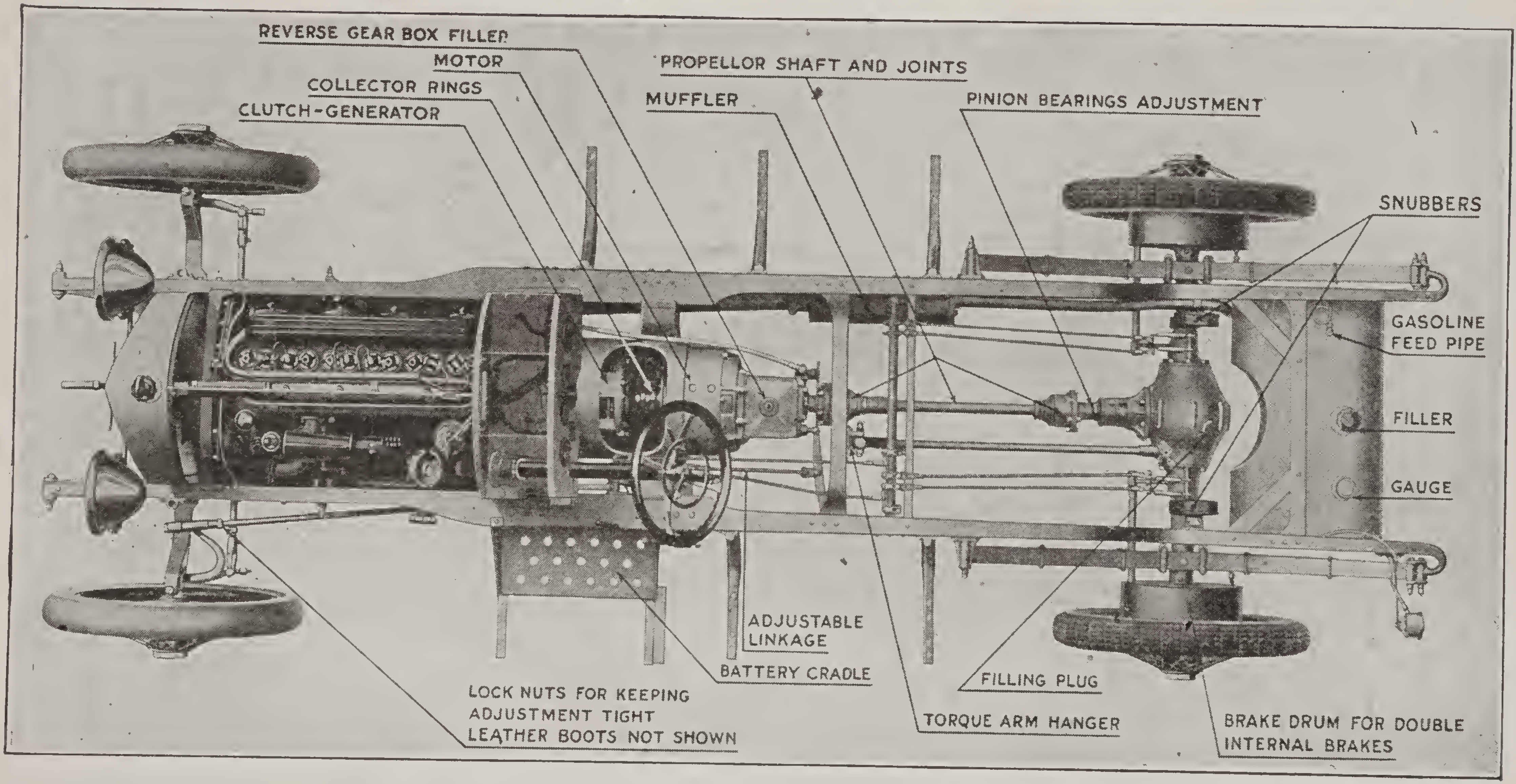


Fig. 293. Plan View of Complete Chassis of Owen Magnetic Motor Car
Courtesy of Baker-R & L Company, Cleveland, Ohio

By introducing variable resistance in the connecting wire, or rather series of wires, the speed may be varied from zero to the maximum, which, as it happens through this booster action, is considerably in excess of what it would be if the motor were driving directly through on high speed without any electrical or mechanical apparatus. The variety of speeds can be anything desired, and this forms the basis for nâming it "The car of a thousand speeds". As a matter of fact only seven speeds are provided for on the steering wheel, which is shown in Fig. 292, but it is perfectly feasible to wire up the car and arrange the quadrant to have twice this number or any other number, as required. On the steering post quadrant, the additional positions of charging, starting, and neutral are to be noted. The neutral position is that in which the engine is idling and the car standing still; or when the car is coming down a grade, the wheels are driving the motor which generates current in the reverse direction, so that the device becomes an electric brake, slowly but surely reducing the speed of the car. The starting position connects the storage battery to the generator armature in order to revolve the engine shaft and thus start it. The charging position can be used at any time to generate electricity for the storage battery.

While this description sounds very different, the chassis is not unlike the average gasoline chassis with a mechanical gear shift, as Fig. 293, showing a view of it from above, brings out. The small unit just back of the motor is a mechanical reverse gear which it has been found advisable to use for one reason, because it gives all the quadrant speeds on the reverse, instead of the usual one. By this arrangement the car has seven fixed speeds forward and seven speeds reverse, together with the possible variations of both, which can be produced by the use of spark throttle and accelerator.

TRANSMISSION TROUBLES AND REPAIRS

Noise in Gear Operation. One of the most common of transmission troubles is a grinding noise in the operation of the gears. This is heard more in bevels than in spurs, but in old transmissions and on the lower speeds it is heard frequently. A good way to quiet old gears, after making sure that they are adjusted rightly and meshing correctly, is to use a thicker lubricant. If thick oil is being used, change to half-oil and half-grease or preferably all grease.

In this respect the repair man or amateur worker may take a leaf out of the book of second-hand car men, who are said to "load" an old and very noisy transmission gear with a very thick almost hard grease in which is mixed some shavings, sawdust, cork, or similar deadening material. When this is done, a graphite grease is generally used, so that the shavings, cork, etc., would not show in case it was necessary to take off the gear-box cover. This material will fill up all the inequalities of the gears and shafts so that temporarily everything fits more tightly, and all the sounding board, or echo, effect is taken out of the transmission case. This sounding-board effect is fully as important as the grinding noise, for many really insignificant noises are magnified by poorly shaped gear cases so as to appear very loud, indicating serious trouble which need immediate attention, when such is really not the case.

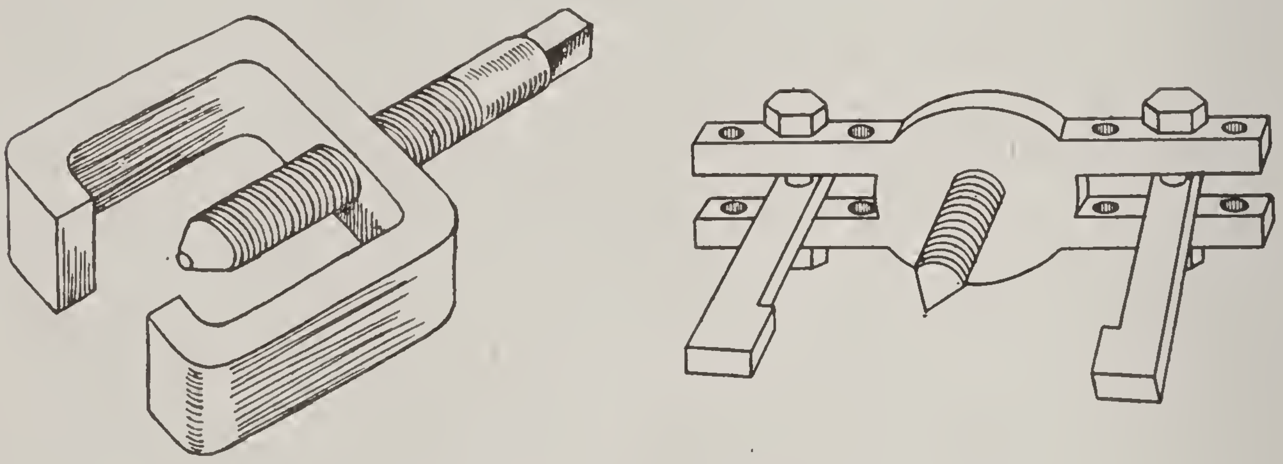


Fig. 294. Types of Gear Pullers

Another source of gear-set noise is a shaft out of alignment, caused either by faulty setting, by worn or loose bearings, or by yielding or cracking of the case. If it is properly set at one end and is out at the other, the trouble will be more difficult to find and remedy.

Heating. Heating is a common trouble, too, but usually this can be traced to lack of lubricant in an old car or to too large shafts or too small bearings in a new one. Sometimes the grease used will cause heating, particularly when long runs are made with the transmission working hard. This is most noticeable when the grease or lubricant is of such a consistency that the gears simply cut holes in it but do not carry any around with them or do not otherwise circulate the lubricant. This can be remedied by making it thicker so the gears will cut it better, by making it thinner so they will splash it more, or by changing the nature of it entirely.

Gear Pullers. One of the principal necessities for transmission work is a form of gear puller. These are like wheel pullers, except that they are smaller and more compact. In Fig. 294, a pair of gear pullers are shown. The one at the left is very simple, consisting of a heavy square bar of iron which has been bent to form a modified U. Then, a heavy bolt is threaded into the back of this or bottom of the U. This will be useful only on gears which are small enough to go in between the two sides of the puller, that is, between the sides of the U, which when in use is slipped over the gear, the screw turned until it touches something solid, as the end of the gear shaft, and then the turning continued until the gear is forced off.

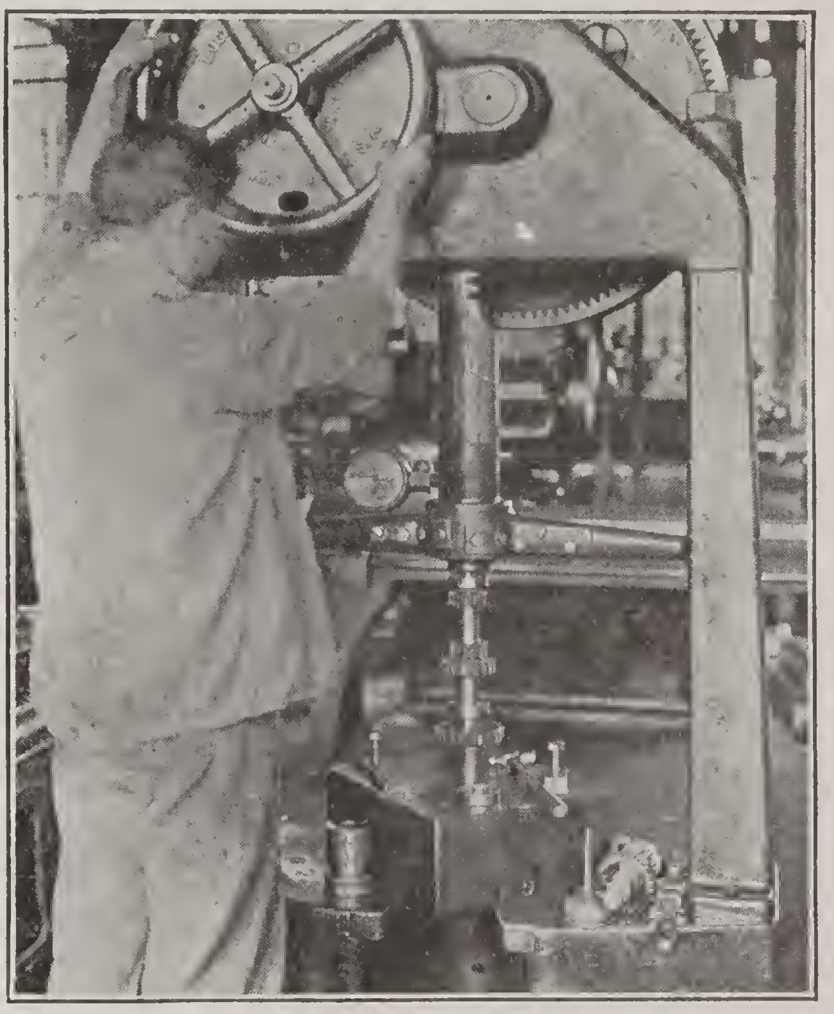


Fig. 295. Method of Pressing Transmission Gear onto Its Shaft

While not as simple as this, the form shown at the right has the advantages of handling much larger gears, and also of being adjustable. As the sketch shows, this consists of a central member having slotted ends in which a pair of L-shaped ends, or hooks, are held by a pair of through bolts. Then there is a central working screw. To use, the hooks are set far enough apart to go over the gear, then slipped around it and hooked on the back. The central screw is turned up to the end of the shaft, and then the turning continued until the gear comes off. There are many modifications of these two; in fact, practically every repair shop in the land has its own way of making gear or wheel pullers. At any rate, every shop should have one.

Pressing Gears on Shafts. The opposite of pulling off gears is putting them on; very often they are designed to be a press fit, which means exerting tremendous pressure. Every repair shop should have some form of press for this and similar work, something similar to the form shown in Fig. 295. In this figure, the man is just beginning to apply pressure to the shaft to force it into the lower gear. The table must be arranged for work of this kind with a solid spot when the shaft does not come through, and with a hole when it does. The work of pressing is usually done in a few seconds, while the preparation, alignment, and starting of the work takes perhaps half an hour or more. It is work which should be done very carefully.

One way in which arrangement can be made for pressing a shaft a considerable distance into a gear and, conversely, for pressing the shaft out of the gear is that shown in Fig. 296. This figure has the additional advantages of being simple, easily constructed, and cheap. A solid base is constructed with a pair of hinged uprights. These can be dropped together with the work between them, forming a modified triangle, the strongest known shape, resting upon its broadest side and thus having the greatest stability. With this arrangement, the press can readily be used for pressing off parts.

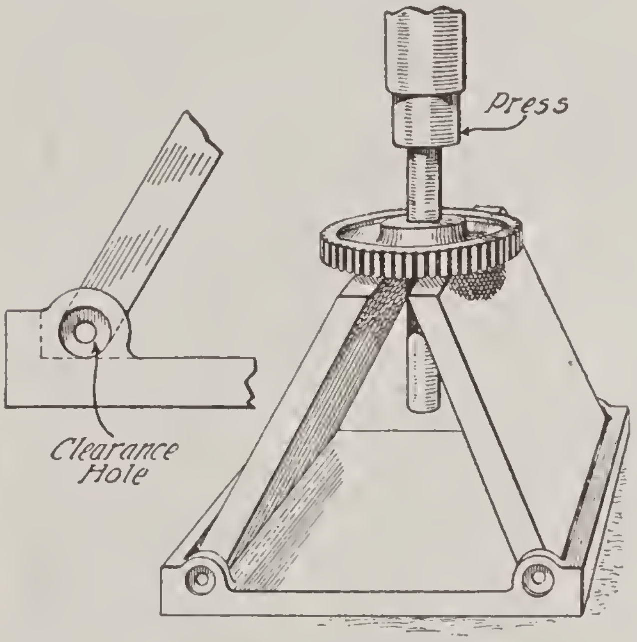


Fig. 296. Home-Made Table for Use in Gear Pressing or Pulling
Courtesy of "Motor World"

Care in Diagnosis. The repair man should use a great deal of care in doping out or diagnosing the trouble in a transmission, for, frequently, what appears at first to be at fault turns out to be all right, and something else is back of the first trouble, which must be corrected before a remedy can be applied. Recently, a repair man figured that a new gear was needed to repair a transmission. This was received from the factory three days later, but when he started to put it in, he found that a bearing was defective; in fact, the defective bearing caused the wear in the gear. This necessitated a further delay of three days in order to get a new bearing.

Poor Gear Shifting. A common transmission trouble is poor gear shifting. This may be due to a number of different things.

For one thing, the edges of the gears may be burred so that the edges prevent easy meshing. When this is the case, any attempt to force the gears into mesh only burrs up more metal and makes the situation worse. Whether this is the trouble or not can be determined very quickly and easily by removing the transmission cover and feeling of the gears with the bare hand; the burred edges can readily be distinguished. If this is the only fault, the transmission should be taken down, the gears taken out and placed in a vise, and the burrs removed with a cold chisel and file.

Poor or worn bearings or a bent shaft or one not accurately machined may cause difficult shifting. If the bearings are worn, the difficulty of shifting will be accompanied by much noise, both in shifting and after. The bent shaft is more difficult to find and equally difficult to fix. A new shaft is usually the quickest and easiest way to remedy the trouble.

Sometimes the control rods or levers bind or stick so that the shifting is very difficult. In case the gears are difficult to "find" or will not stay in mesh, the fault may be in the shifter rod in the transmission case. This usually has notches to correspond to the various gear positions, with a steel wedge held down into these notches by means of a spring. The spring may have weakened, may have lost its temper, may have broken, or for some other reason failed to work. Or with the spring in good working condition, the edges of the grooves or notches may have worn to such an extent as to let the wedge slip out of, or over, them readily.

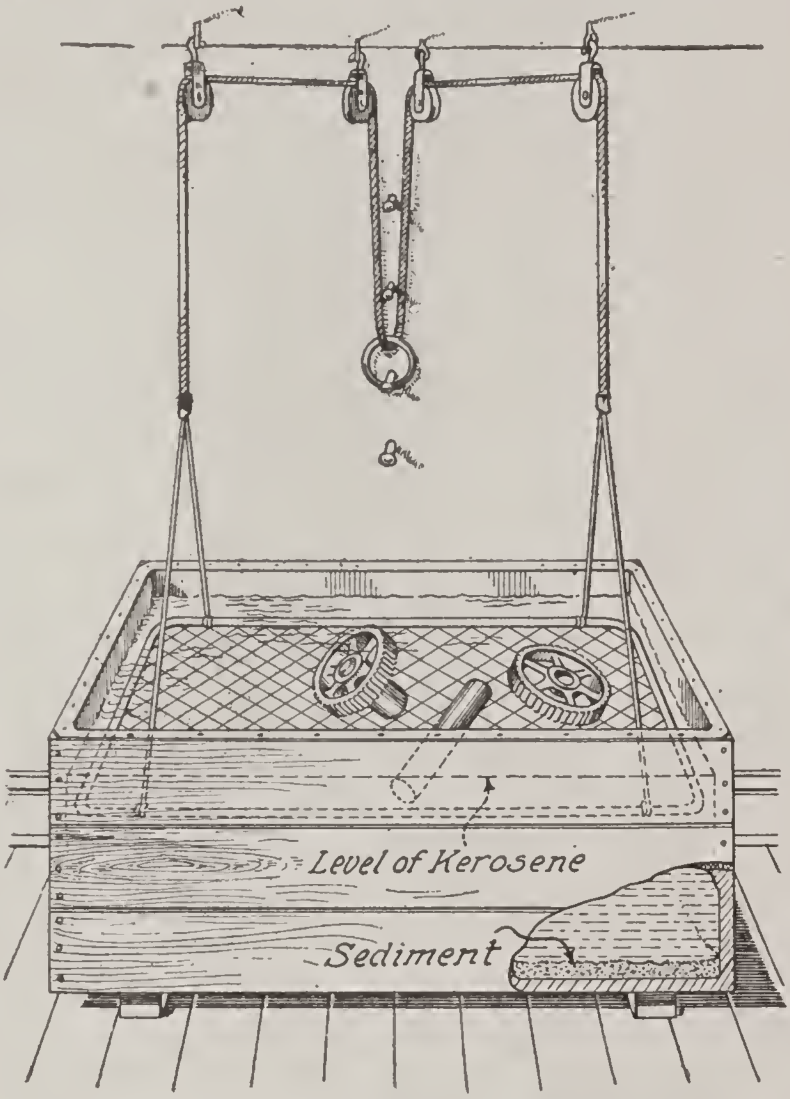


Fig. 297. Tank and Basket for Cleaning Gears and Other Parts

Courtesy of "Motor World"

Cleaning Transmission Gears. When the transmission is taken out of the case and has to be taken apart, and particularly if it has not been cleaned for a long time previously, it is advisable to clean all the parts thoroughly before attempting to work with them. The best way to clean the parts is to have a special cleaning tank. In Fig. 297 one of these is shown, which is not unlike the baskets used in some hardening processes. It consists of a deep metal or metal-lined tank and a basket or tray, which is an easy fit in it, suspended from above by wire cables. The cables are brought together on the wall, where a ring joining the ends and a series of nails or hooks make it easy to hold it at any desired elevation, either in or out of the tank. The tank is filled preferably with kerosene. As soon as a part has been removed from the transmission, it is thrown into the basket, and when this is filled or all the parts are in it, it is lowered into the kerosene and allowed to stand, for a couple of hours if possible, but, if not, for as long as can be. When thoroughly soaked, the basket should be raised above the level of the liquid and allowed to drain thoroughly. If it can be left for an hour or so to

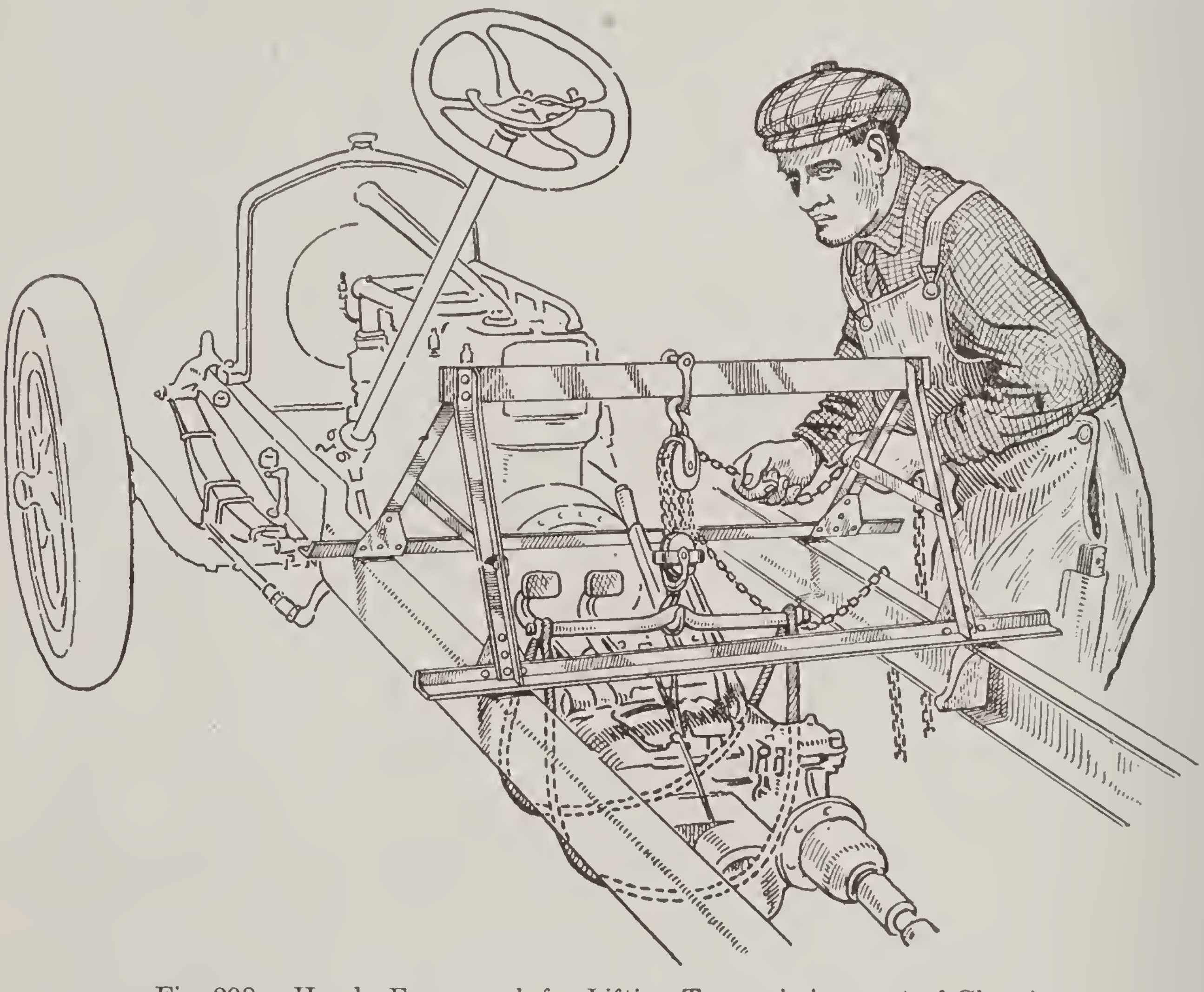


Fig. 298. Handy Framework for Lifting Transmissions out of Chassis

drain, all trace of kerosene will disappear, while the gears, shafts, and other parts will be like new.

Lifting Out Transmissions. When the trouble has been found to be in the transmission case or in some part that necessitates complete removal, it is often a tremendous job to get the unit out. Some units are attached from below and are not so difficult to detach. They are lowered by means of a platform of boards set on two or more jacks. But when it must be removed from above and no overhead beam is available, the hoist shown in Fig. 298 will be found very handy. As will be seen from the sketch, this hoist is simply a triangular framework constructed from angle iron to have the minimum height which will allow removal of the unit. The chain fall is attached to a hook in the center, and the chains put around the case. When lifted up close into the V of the framework, the whole transmission can be put onto horses and moved along the chassis, or boards can be put under it and over the chassis frame to allow it to be worked there. Or, if desired, it can be lowered onto a creeper or other low platform with wheels and moved out of the way. This rigging can be used for many other similar purposes, although it is not suitable for the removal of an engine, radiator, or other part or unit which extends far above the chassis frame.

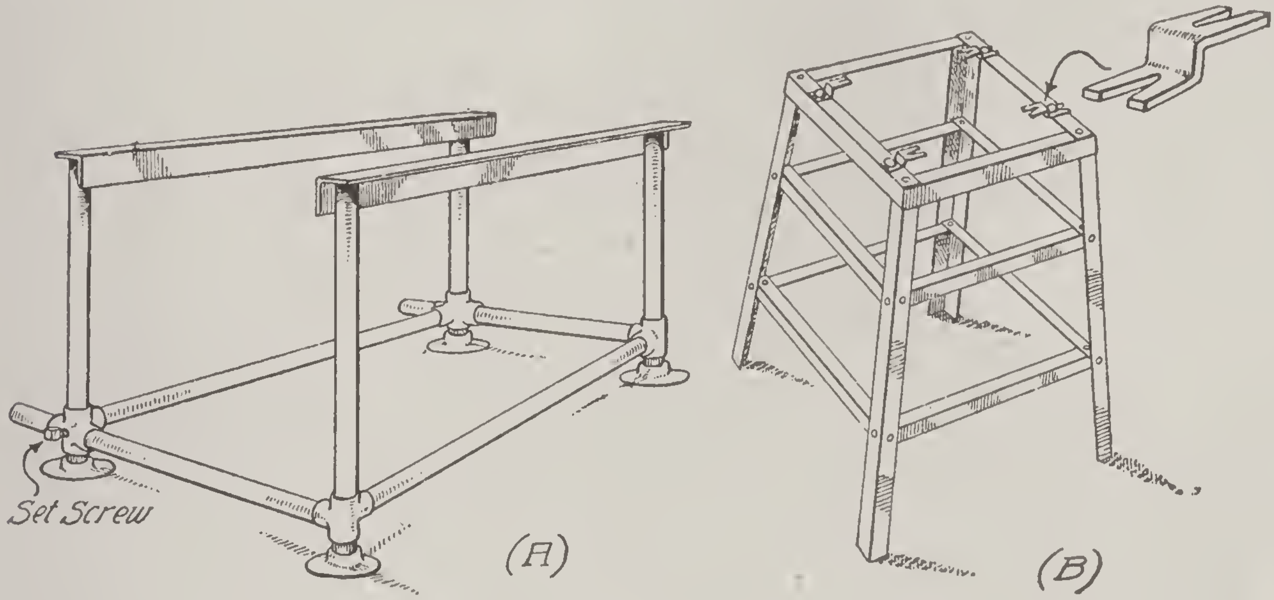


Fig. 299. Two Forms of Useful Transmission Stands
Courtesy of "Motor World"

Transmission Stands. When the transmission has been removed, if the work to be done upon it is all extended, a stand to support it is desirable; in fact, a necessity, if the work is to be done right. A pair of stands are shown in Fig. 299, the one at the left is made from pipe fittings and angle irons in such a way that the width between the rails can be varied to suit the transmission or engine. The stand at the right is more of a specialized type. It is constructed for a certain transmission and has clips to support it in the same way that it is held in the chassis. The latter frame may be smaller and more compact than the former, but the wide range of uses to which the former can be put make it more desirable in the average shop.

Working in Bearings. When a great many bearings of any one transmission are fitted, it is well to make a jig for working in the cases to an exact size for the bearings, whether these be oversizes or not. Such an outfit, Fig. 300, shows an aluminum transmission case with a pair of jigs for scraping its bearings into the case. These jigs are made of steel and are constructed to a very accurate size, the surfaces being hardened so they will show no wear. The jigs are painted with Prussian blue, put in place and turned, the markings scraped by hand, the jigs again put in place and turned, and this process repeated until a perfect bearing surface is obtained. Starting with an unknown size on the case and a known size of bearing which must go in it, a few of these jigs will soon save their cost in labor and time, by quickly producing the necessary size of case to take the bearings.

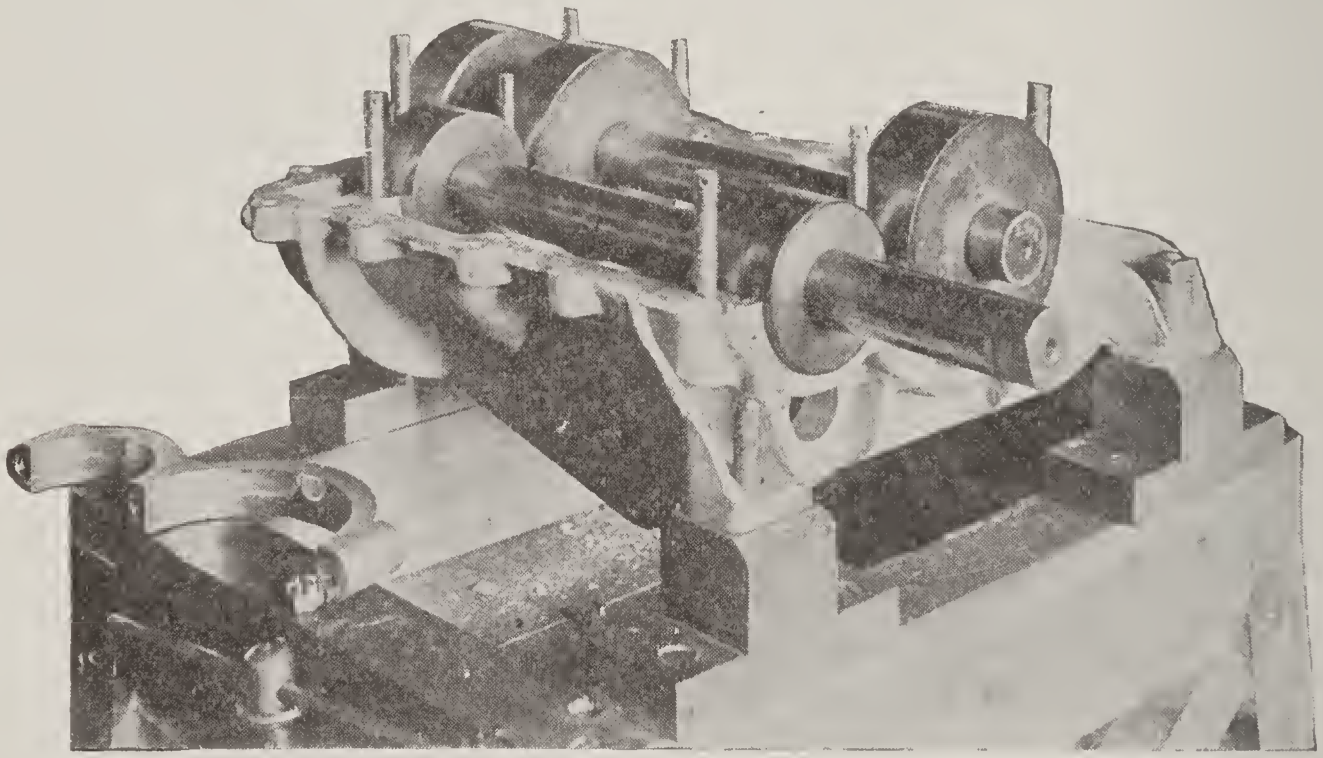


Fig. 300. Method of Fitting Transmission Case Bearings with Dummy

Saving the Balls. If a great many ball bearings, particularly from transmissions, are used, and many bearings scrapped, it is advisable to save the balls. These balls will come in handy later for replacement or other uses. Moreover, balls are expensive, and good ones are hard to obtain. A handy way to take care of balls, without much work beyond cleaning thoroughly in the kerosene tank, is to construct a cabinet like that seen in Fig. 301. There are four drawers—or more if desired. The bottom of each drawer is a steel plate drilled as full of holes as possible of the next smaller size, that is, a clearance size for the next round figure size. Then the cabinet does the sorting, all balls being put into the top drawer. The next smaller size is retained in the second drawer, the third size in the next, and so on. When using balls out of these drawers, the micrometer should be used to determine their exact size.

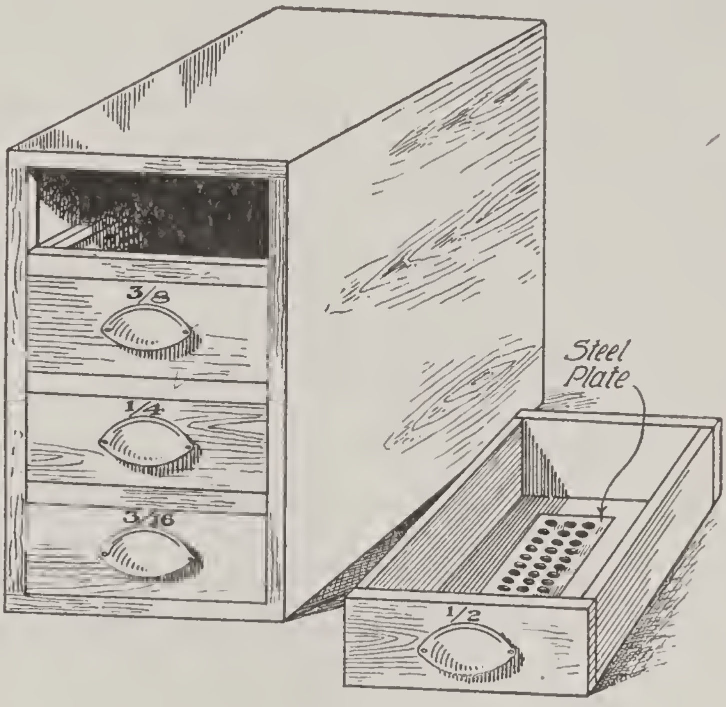


Fig. 301. Easy Way of Sorting and Keeping Old Bearing Balls
Courtesy of "Motor World"

Handy Spring Tool. In the Ford transmission-band assembly there are three springs which it is difficult to assemble because of the trouble in holding so many things at once. To eliminate this trouble, the tool, shown in Fig. 302, made from flat bar stock, can be constructed. The handles, if they could be called that, are pivoted together and carry a kind of flat jaw with three notches at one end. When the two of these are squeezed together by means of the screw and handle at the other end, the flat plates will hold the three springs tightly enough so that all can be inserted in their proper positions

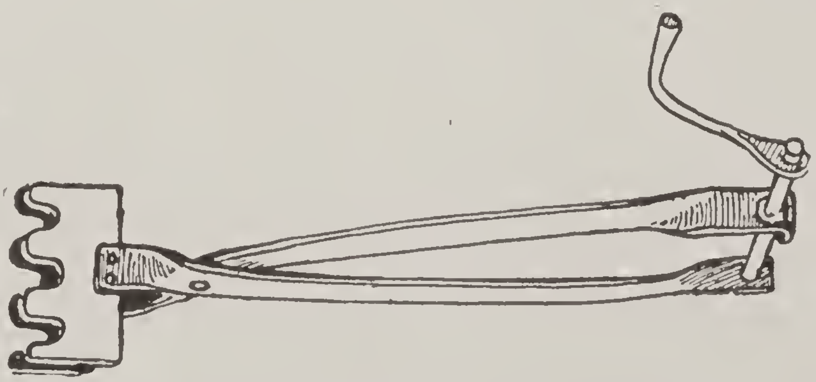


Fig. 302. Handy Spring Tool for Ford Assembly

at once by using but one hand. Tools of this kind, which save a great deal of the workman's time and thus save both time and money for the owner of the car, should, and in fact do, distinguish the well-equipped repair shop and garage from the old-fashioned kind which is in the business only for the money and not too particular how it is gotten.

In transmissions of the planetary type, there is little or no trouble except with the bands. If these are loose, the gears will not engage and the desired speed will not result. If they become soaked with grease, oil, or water, they will not work as well as if kept clean and, in the case of excessive grease, will slip continually. If the band lining becomes worn, it should be treated just as a brake lining is. When inspected for wear and found not badly worn but slippery, it may be cleaned in gasoline and then in kerosene, after which a saw, hacksaw, or coarse file may be used to roughen it. Sometimes greasy bands can be fixed temporarily—say, enough to get the car to a place where tools, materials, and facilities for doing the work are available—by sprinkling them with powdered rosin or fuller's earth. The former should be used sparingly because it will cause the band to bite or grab hold when forcibly applied, and at times has been known to cut into and score a cast-iron drum. As a rule, planetary transmission bands should be handled in the same way as ordinary brake bands, as to lining and relining, roughness of surface, lubrication, etc.

Possible Transmission Troubles. A combination of clutch and transmission in which the principal troubles incident to these units are indicated is presented in Fig. 303. In this type of clutch, the greatest possibilities of trouble lie in the burring of the discs or in a lack of spring adjustment. If the discs burr, the burrs can be filed off with a fine file, while the latter trouble is avoided by merely tightening the spring-adjusting bolt, trying the effect of this and tightening again, until the correct and satisfactory position is obtained.

In transmissions, the possibilities of trouble include the following: burred teeth; gears worn where they slide along the shafts on keys or in keyways; looseness in the main bearings; and play in shifter rods or their locks. Where the gears clash, one against the other in shifting—unless the faces of each have been chamfered and rounded off nicely and are well hardened at these points—a cutting action which gradually wears a high burr in one or both gears is liable to be set up. When the two are in mesh, the burrs are on opposite sides and contact with the meshing gear. This contact will make a continuous noise. Its remedy is the removal of the gear, the filing off of all raised portions, the filing or grinding out of all low spots cut into the teeth, and subsequent hardening to make repetition impossible.

If the gears have worn at the center hole where they slide on the shaft, either in the round hole or at the keyway, this must be fixed at once. In the former instance, the gear can be bushed, and the bushing bored out to fit the shaft, while in the latter, a slightly larger key may be fitted into the shaft and the keyway may be recut to accommodate it. Where the keys have been let into the shaft, they may become worn in one spot or at the ends. If the wear is all in the key, it can be replaced with another of the same size made slightly harder in the process.

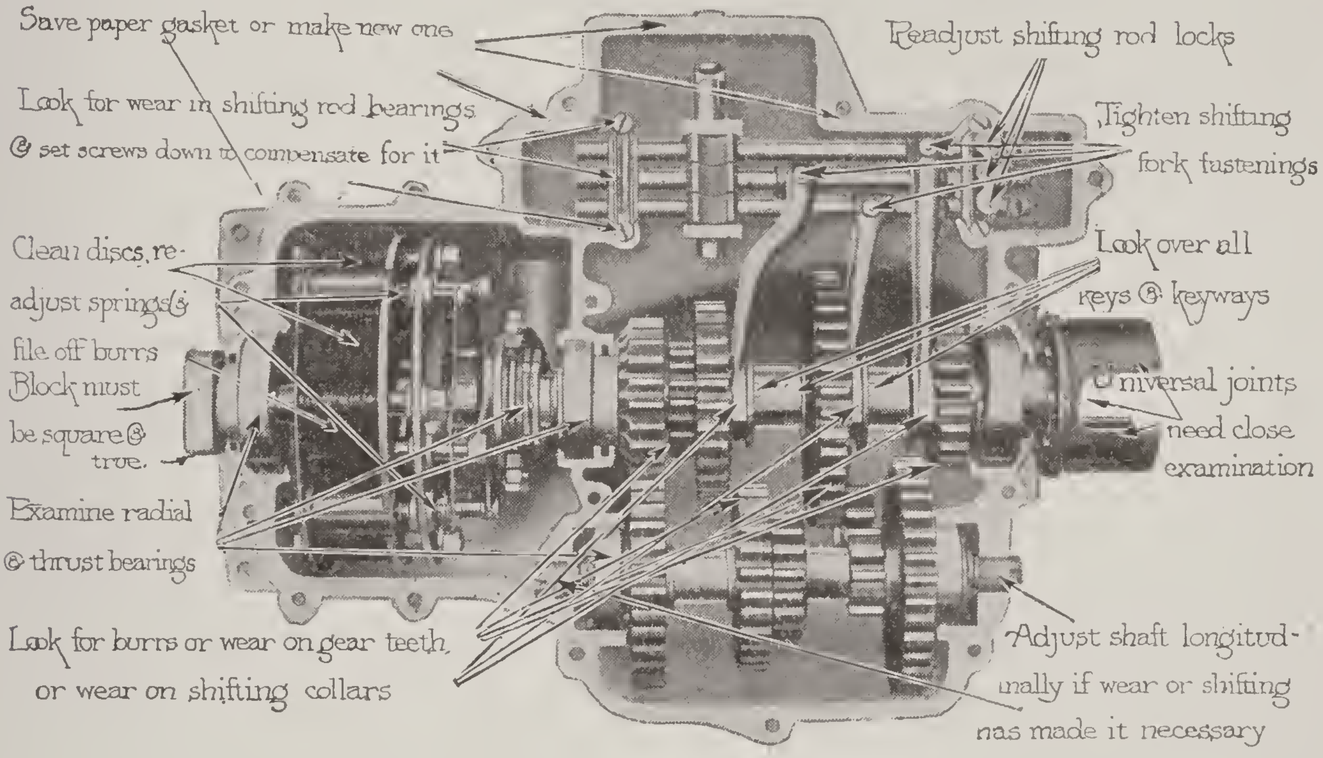

Save paper gasket or make new one
Look for wear in shifting rod bearings & set screws down to compensate for it
Clean discs, re-adjust springs & file off burrs
Block must be square & true.
Examine radial & thrust bearings
Look for burrs or wear on gear teeth, or wear on shifting collars
Readjust shifting rod locks
Tighten shifting fork fastenings
Look over all keys & keyways
Universal joints need close examination
Adjust shaft longitudinally if wear or shifting has made it necessary

Fig. 303. Transmission Troubles Illustrated

If the main bearings are of the roller type, the wear may be taken up by readjusting the position of the roller on the cone, but if they are of ball or plain bushing form, replacement is almost the only remedy, unless it happens that in the case of a plain bush the bush is split, so that something may be filed off of the two contacting sides, and the holes trued out to this new size. In that case, the advice previously given under the subject of Plain Engine Bearings will be applicable.

Play in the shifting rods may be traced to one of two things: looseness at the connection of two rods or of a rod and a lever; or looseness in the bearings. The former inevitably requires a new and slightly larger pin driven into the place occupied by the previous member. Loose bushings will mean new ones if the trouble is serious, for this form is almost always of the solid and non-adjustable type. In many cases where wear occurs on a solid plain bearing used on the end of a plain round shaft, if peening cannot be resorted to, the shaft may be turned down a very little bit, say $\frac{1}{16}$ inch, the bushing turned out an equal amount, and a thin sleeve bushing made of this thickness all around and forced into the previous member. This saves reboring the case, which is an expensive and difficult job, while both the shaft and bushing jobs are simple ones.

If a serious defect develops in the case, it may be cleaned out and welded. This is not a job for the amateur, but the closing of a simple crack, no matter how long, would be an easy proposition for the owner of a welding outfit; moreover, it would be a very short quick job. Autogenous welding should always be resorted to as soon as a crack or break is detected, for this may save the expense and delay of a whole new case, the welding costing from 50 cents to $1, while the new case easily may amount to $50.

SUMMARY OF TRANSMISSION TROUBLES

Lubricating Transmission Gears. The transmission case should be filled with lubricant to a depth of several inches. Care should be exercised at frequent intervals to see that a proper amount of lubricant remains in the transmission case. Different makers recommend different kinds of lubricants for transmissions. In light cars a mixture often used consists of equal proportions of light grease and machine oil. In heavier cars a heavy graphite grease is often used. The proper lubricant depends upon the types of bearings used; thus for ball-bearing transmissions, no oil need be added.

Change-Speed Lever Indicates Some Impediment in Transmission. It is desirable to look for broken or mutilated gears, broken bearings in transmission shafts, sticking or misalignment of gear shafts or of their operating mechanisms.

Adjusting Annular Bearings. Makers recommend that the inner race be pinched so tight that movement is impossible; the outer race is sometimes allowed a little freedom—.002 to .003 inch.

GEARS

Since the whole subject of transmission concerns itself with gears, it will not be out of place to discuss the gears themselves and describe the many different kinds in use. Speaking broadly, the gears used may be classified according to the position of their axes, relative to one another. Thus we have axes parallel and in the same plane; parallel but not in the same plane; at right angles and in the same plane; at right angles and not in the same plane; at some other angle than a straight or a right angle and in the same plane; and the same, but not in one plane. These classes give us the forms of gear in common use, viz, spur gears, bevel gears, helical gears, herringbone gears, spiral gears, and worm gears.

TYPES OF GEAR-CUTTING MACHINES

Before discussing these various kinds of gears, it may be wise to familiarize the reader with the special features of different types of gear-cutting machines. Formerly, the teeth were cut, one gear at a time, in the milling machine, this being practically a hand operation, since all movements of the gear or cutter had to be made by hand. Later, improvements made it possible to cut more than one gear at a time, which resulted in lowering the cost, but did not eliminate the hand work.

Step by step special machinery was developed for this work, until finally a perfected machine was brought out which did all the work. With this machine, the workman placed the cutter on the machine spindle, set the gear blanks into position, and started the machine, after which it went on automatically, cutting tooth after tooth to a correct shape, until the gear was finished, when it was again necessary for the workman to shut it off and, after taking out the finished gears, put in a fresh supply of gear blanks.

Many machines have been devised and perfected in recent years owing to the demands of the automobile manufacturers. By having a battery of gear-cutting machines handled by a single man, the cost of gear cutting has been brought down to the absolute limit in addition to a decided gain in gear accuracy.

Whiton Gear-Cutting Machine. The Whiton automatic gear-cutting machine is shown in Fig. 304. The cutter is carried by the spindle *A*, which is journaled in a saddle *B* sliding upon the swinging carriage *C*, and is capable of adjustment at any angle necessary to cut bevel gears. The machine, as shown, is arranged for cutting spur gears. The cutter arbor *A* is driven by the pulley *D* at the back of the machine, acting through a system of gears not shown. The blank to be cut is held on an arbor fitted into the vertical spindle *E*, with its upper end supported by a center in the arm, adjustably clamped to the column *G*. The traversing screw *H* has a graduated dial. A gage provided centers the cutter, and graduated stops are used for setting over the cutter in bevel gear cutting and for setting over the blank. At *J* are the gears of the indexing mechanism.

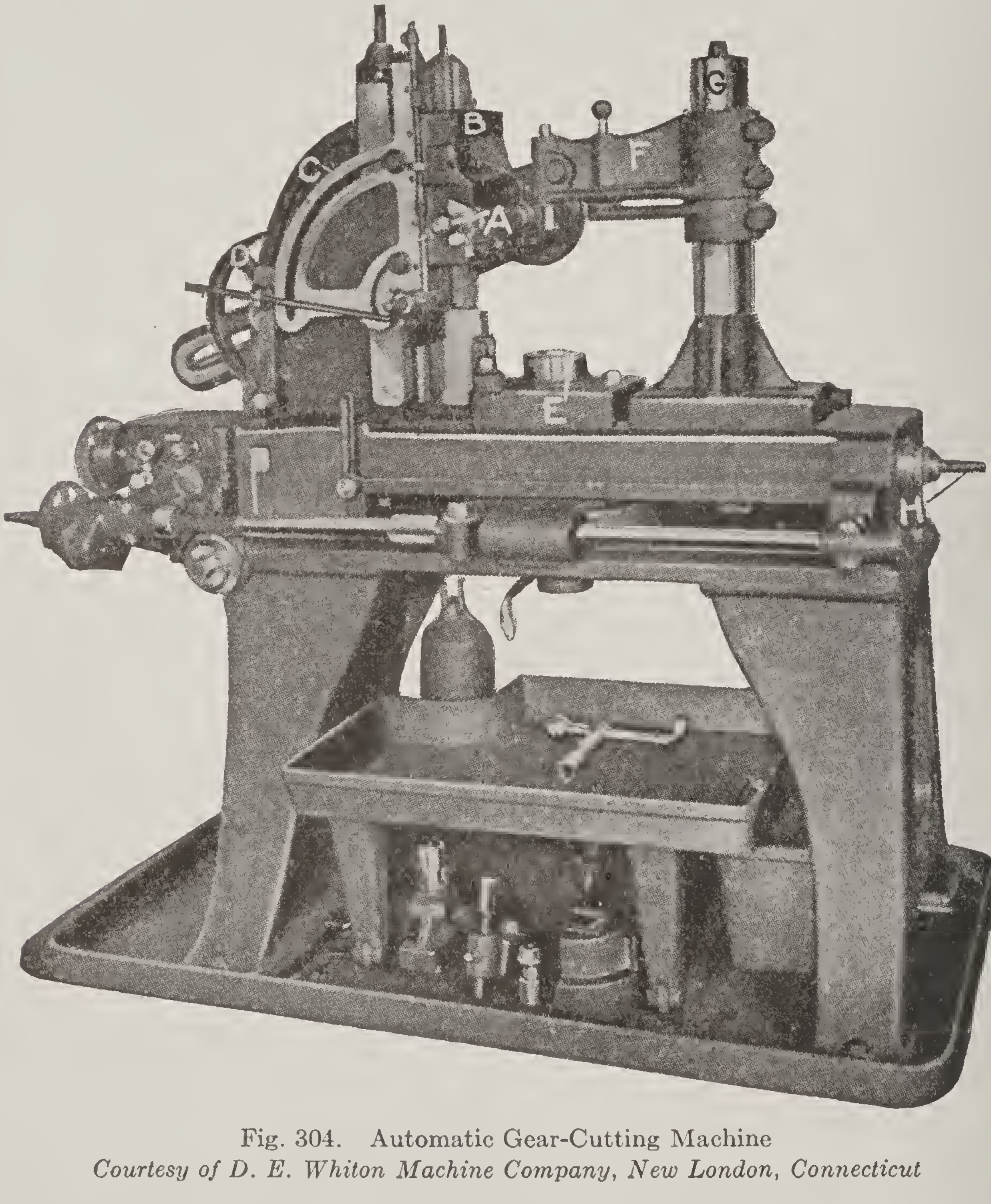


Fig. 304. Automatic Gear-Cutting Machine
Courtesy of D. E. Whiton Machine Company, New London, Connecticut

Brown and Sharpe Gear-Cutting Machine. Fig. 305 represents a Brown and Sharpe gear-cutting machine. The gear blank is carried on an arbor fitted to the horizontal spindle *A* and supported by the outer supporting bracket *B*. The indexing mechanism is in the rear of the indexing wheel *C*. The cutter is carried by the cutter spindle *D* mounted in the traveling carriage *E*. In smaller machines the base upon which this carriage slides is pivoted so as to be set at any required angle for cutting bevel gears. The machine is entirely automatic in its action. It has an attachment for cutting internal gears.

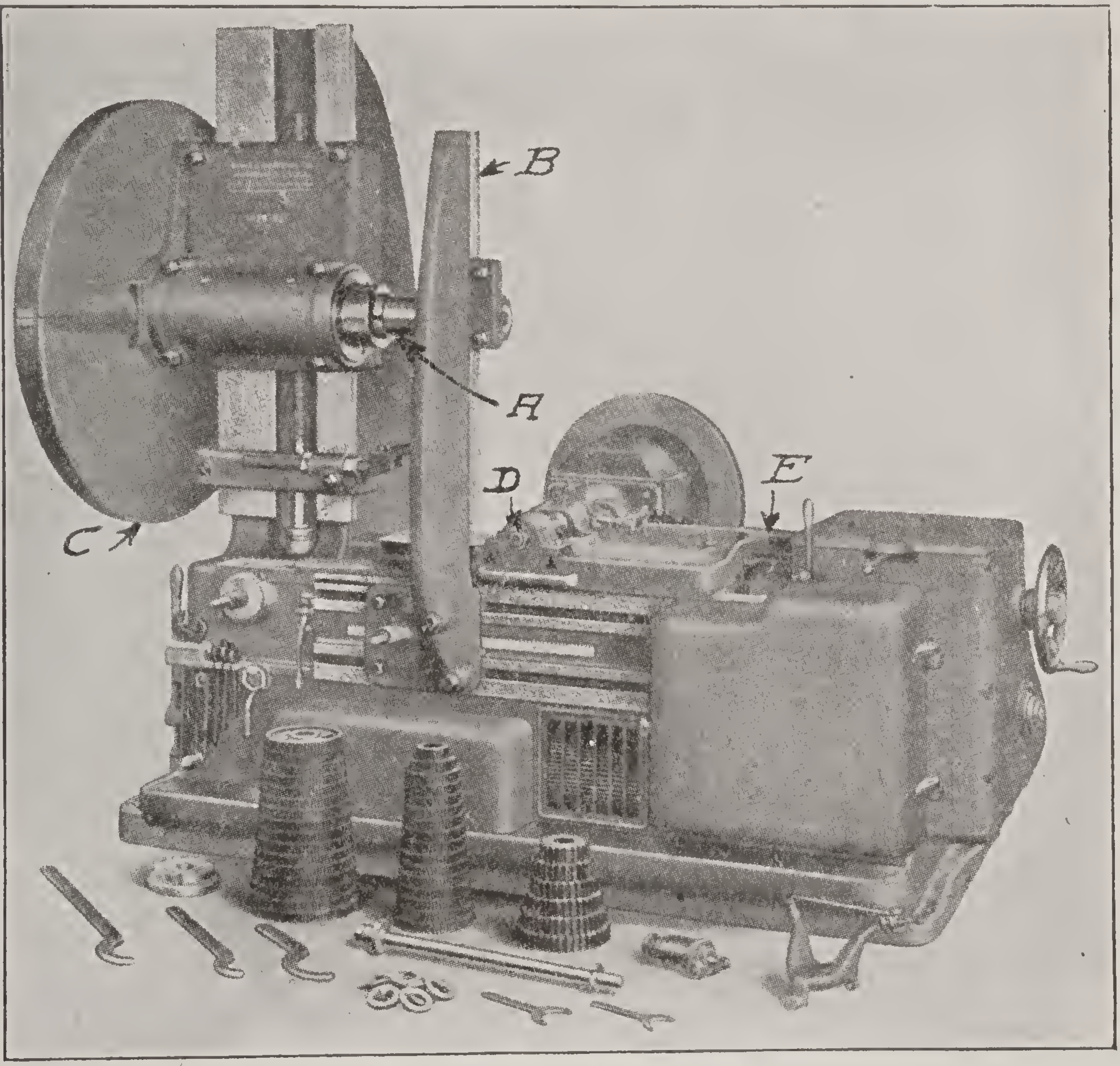


Fig. 305. Number 6 Gear-Cutting Machine
Courtesy of Brown and Sharpe Manufacturing Company, Providence, Rhode Island

Automatic Gear-Cutting Machine. The automatic gear-cutting machine built by Gould and Eberhardt is shown in Fig. 306. It is of the same type as that built by Brown and Sharpe and possesses some excellent features. The gear blank and cutter are mounted in a similar manner, and the adjustments are made at much the same points. It is furnished with attachments for hobbing worm gears and for cutting racks and internal gears. The one shown is not adapted for cutting bevel gears.

Becker Gear-Cutting Machine. The Becker Milling Machine Company gear-cutting machine, Fig. 307, is of the milling-machine type. It was designed by Amos H. Brainard, a builder of milling machines. The gear blank is mounted upon an arbor fitting a taper hole in the work spindle *A* or fixed upon an arbor and mounted on centers. The cutter is mounted upon a cutter arbor *B* journaled in a sliding saddle *C* whose support *D* is pivoted to the machine knee so as to be adjustable to any angle required for cutting bevel gears as well as spur gears. The machine is entirely automatic in its action.

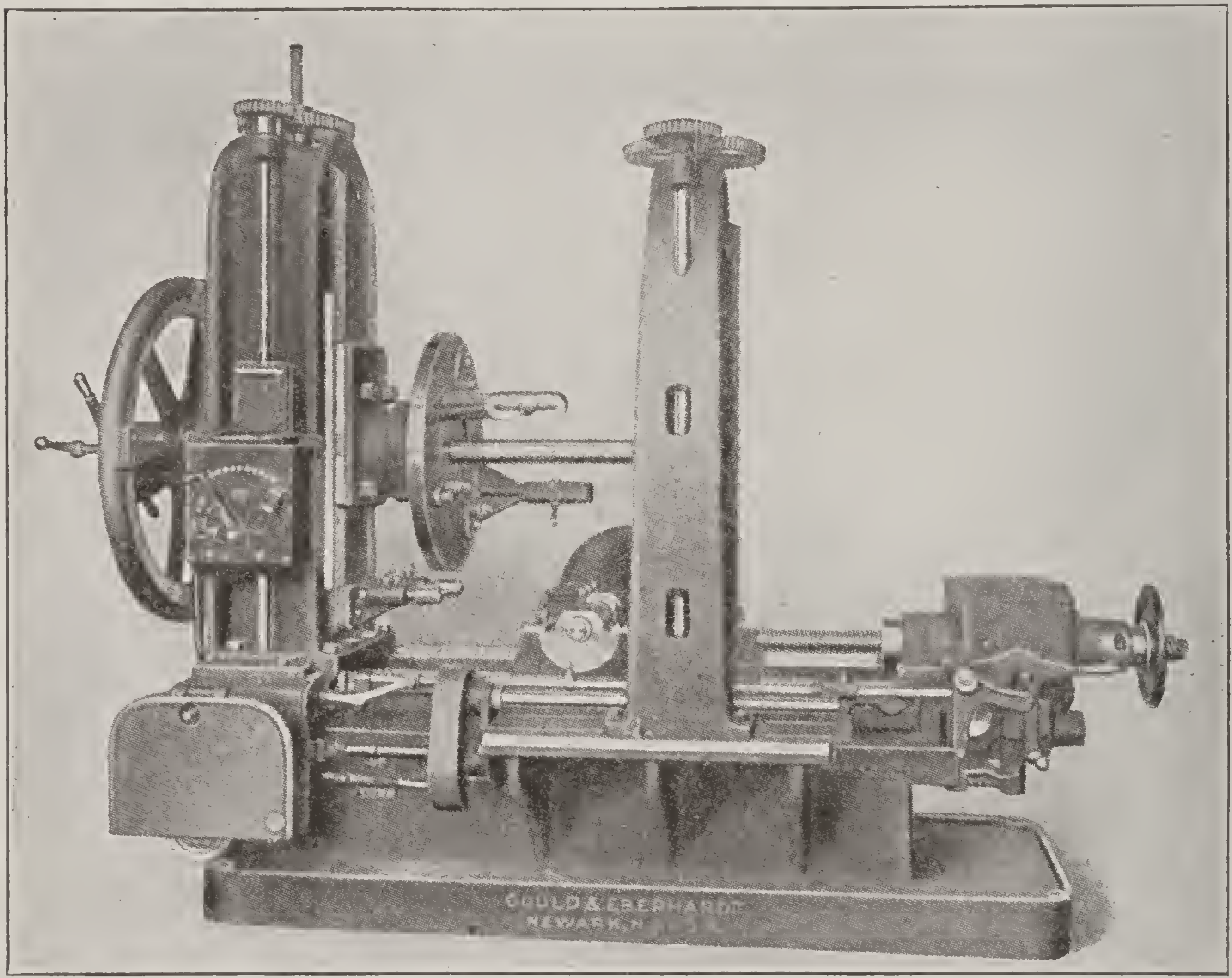


Fig. 306. "New Type" Gear-Cutting Machine Entirely Automatic for Cutting Spur Gears Only
Courtesy of Gould and Eberhardt, Newark, New Jersey

Fellows Gear Shaper. The Fellows gear shaper, shown in Fig. 308, is a distinct type in construction and action. The gear blank is mounted on the vertical work spindle *A*, which has on its lower end and within the casing *B* an indexing worm gear operated by the change gears at *C*. These are driven from the cone pulley *D* by means of the vertical shaft *E* with a very gradual but continuous motion as the vertically reciprocating cutter *F* forms the teeth on the blank, gradually rotating in unison with the rotation of the blank. The reciprocating movement of the ram carrying the cutter is produced by suitable mechanism within the casing *H* operated by the shaft *G*. The machine is automatic in its action and cuts spur gears and internal gears. A modified form of machine is adapted to cutting the teeth of racks. The cutting action is that of planing.

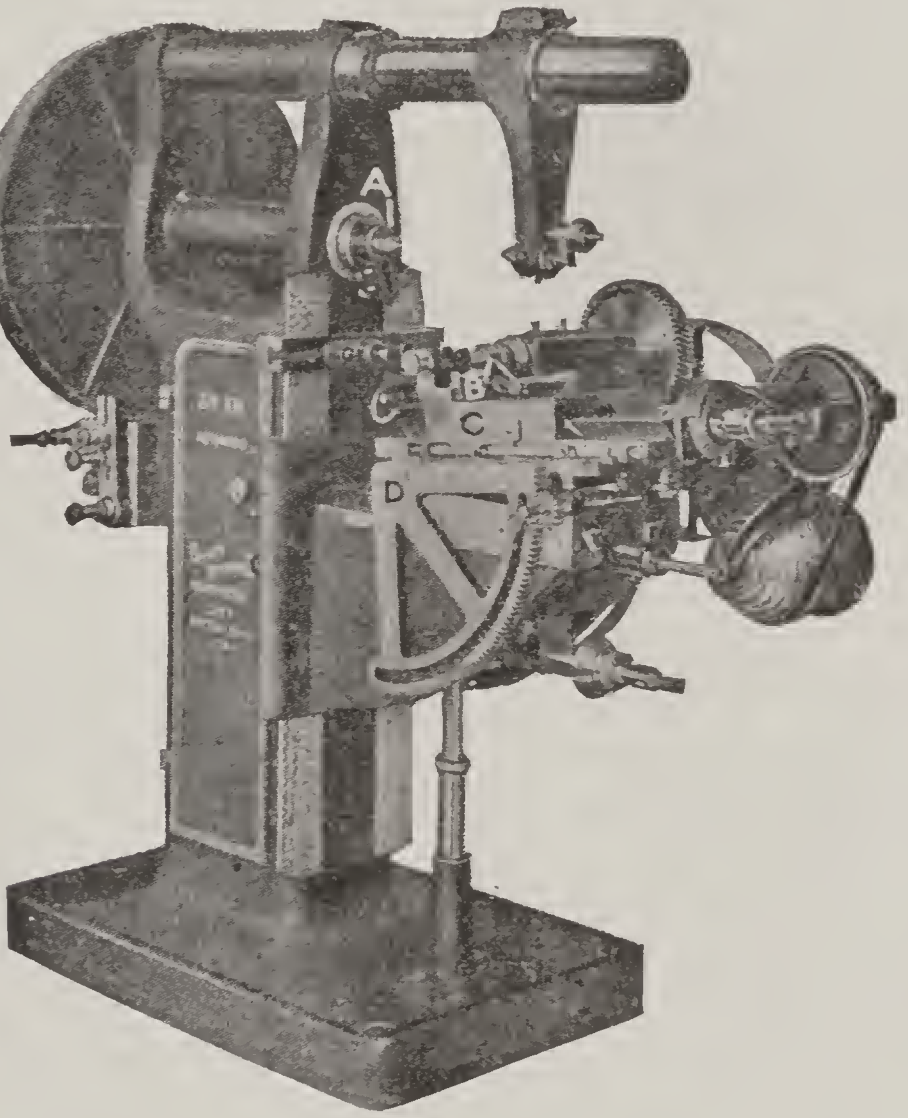


Fig. 307. Gear Cutter

Courtesy of Becker Milling Machine Company, Hyde Park, Massachusetts

Gleason Gear Planer. The Gleason gear planer is shown in Fig. 309. It is an excellently designed machine with a single tool having a narrow rounded cutting point for planing gear teeth. The gear blank *A* is mounted on a horizontal spindle having at its rear end a suitable automatic indexing mechanism *B*. The tool *C* is carried in a reciprocating tool block *D* which travels upon a swinging carriage pivoted at E directly under the apex of the base cone of the gear blank. The exact curve and direction of its feed are controlled by one of the formers, mounted upon the triangular former carrier, which may be rotated so as to bring either former up to its operative position, making a rest and guide on the outer end of the swinging carriage for the friction roller K. Of the three formers, one is used for a roughing cut, and the other two for the upper and under sides of the tooth. Being placed at a considerable distance from the pivot upon which the carriage swings, they are made many times larger than the tooth, and great accuracy of form is thereby secured. The roughing cut is frequently made with a rotating cutter on an ordinary gear-cutting machine. Modifications of this machine are built upon the same principle specially for cutting spur gears.

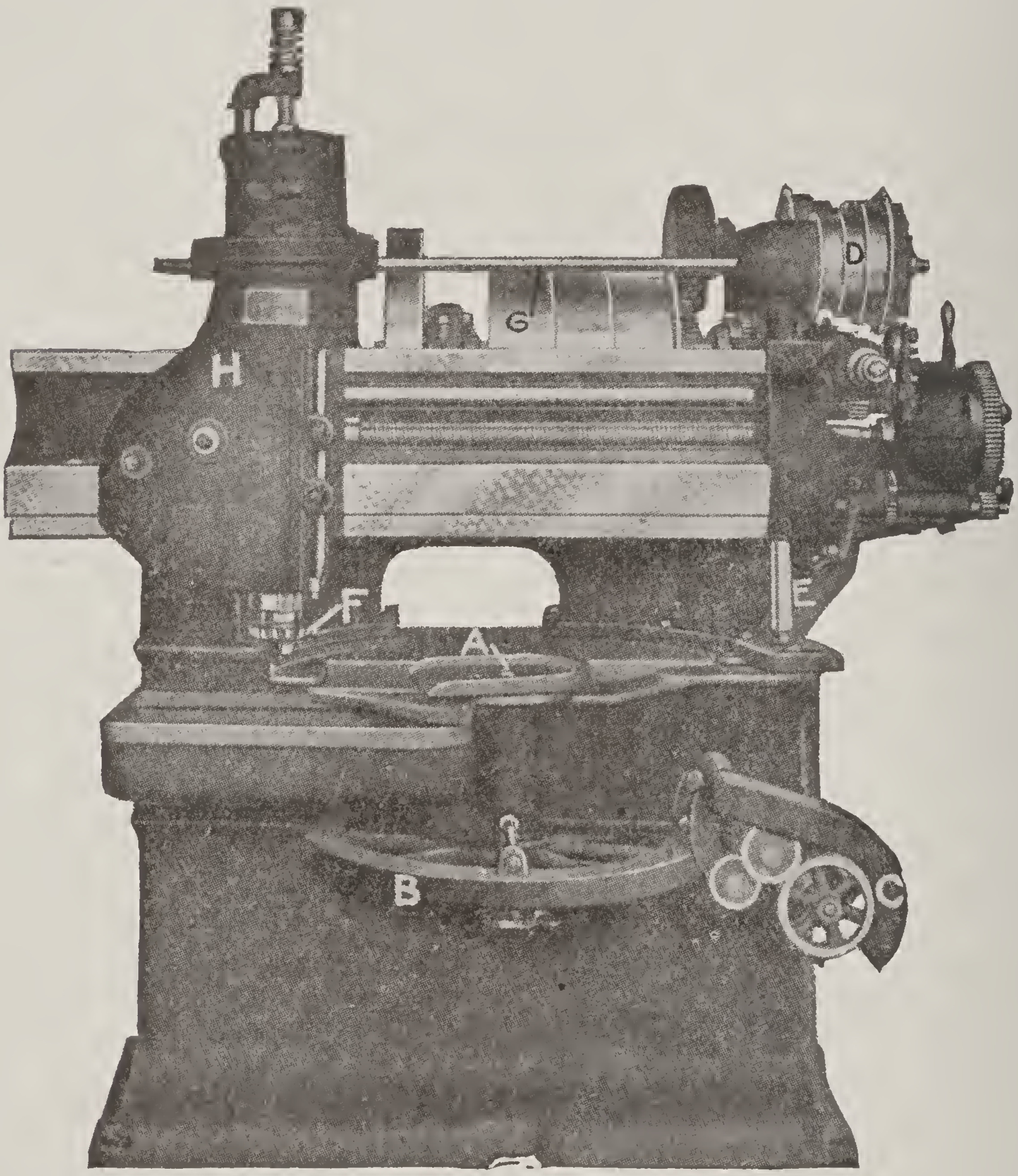


Fig. 308. Gear Shaper
Courtesy of Fellows Gear Shaper Company, Springfield, Vermont

Bilgram Gear-Planing Machine. The Bilgram gear-planing machine, shown in Fig. 310, operates upon a principle similar to that

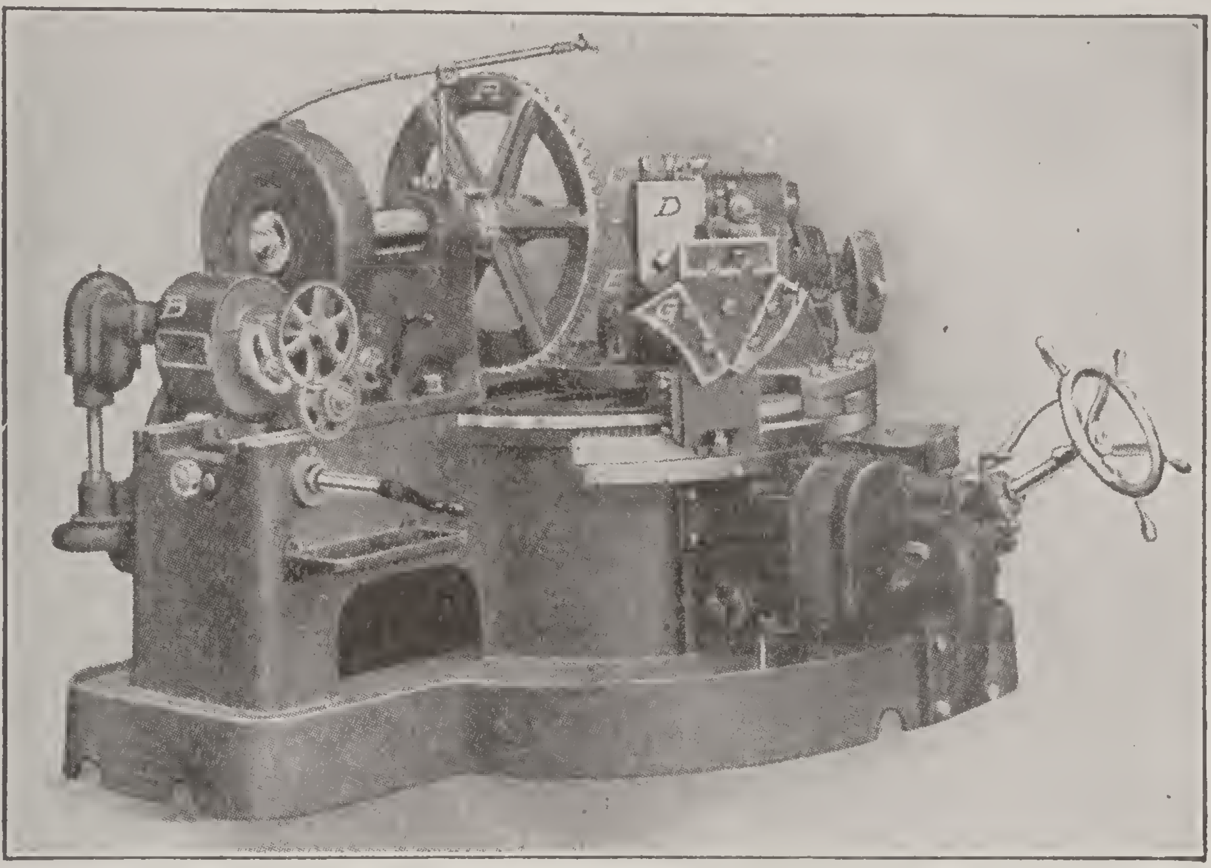


Fig. 309. Gear Planer
Courtesy of Gleason Tool Company, Rochester, New York

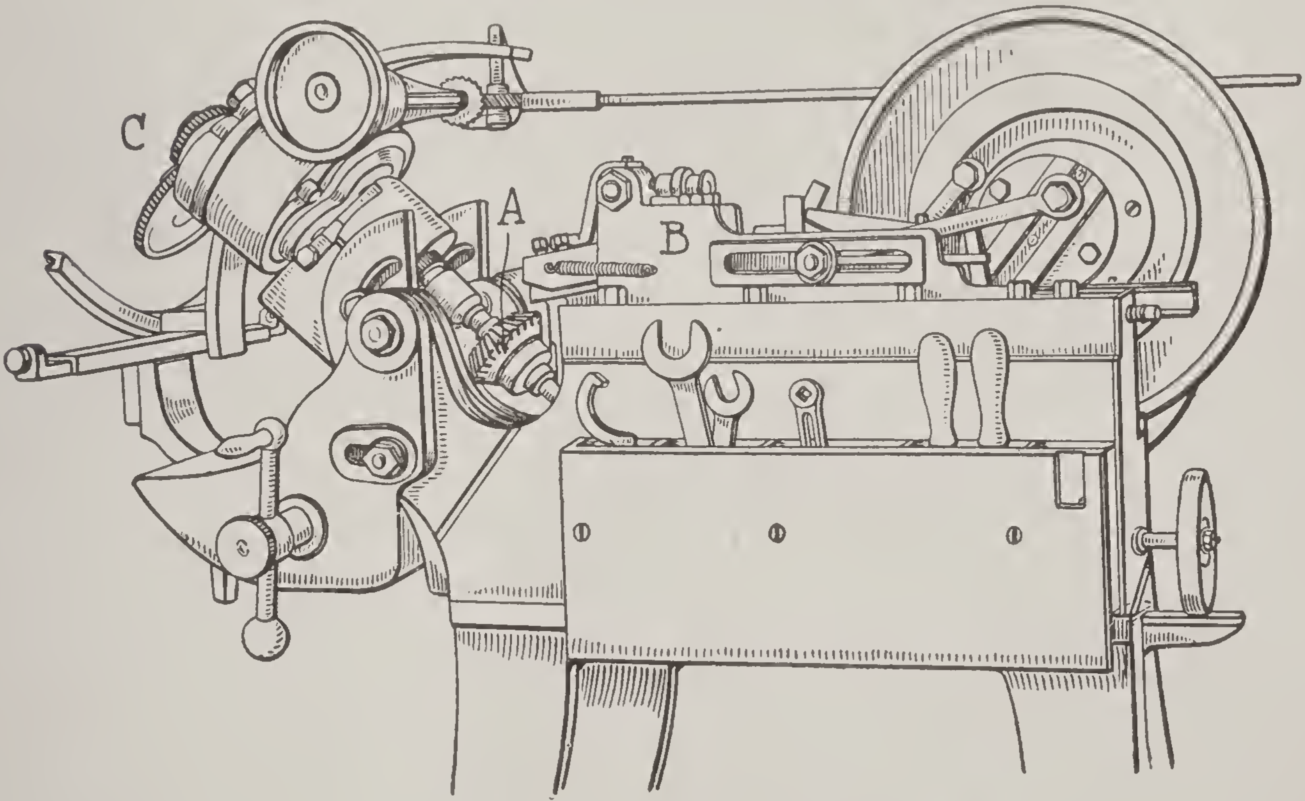


Fig. 310. Gear-Planing Machine

of the machine just described, but with this important difference. In the Gleason machine, the tool moves so as to trace the exact contour of the side of the gear tooth, in addition to its reciprocating movement for cutting. In the Bilgram machine, on the other hand, the tool has only a reciprocating motion, while the gear blank and its supporting mechanism are given the rolling motion similar to that imparted by one rotating gear to another, which is that of a rolling cone. To accomplish this motion, the axis must, in the first place, be moved in the manner of a conical pendulum; therefore, the bearing of the arbor which carries the blank is secured in an inclined position between two uprights to a semicircular horizontal plate, which can be oscillated on a vertical axis passing through the apex of the base cone of the blank. To complete the rolling action, the arbor must, in the second place, receive simultaneously the proper rotation; this effect is produced in the machine by having a portion of a cone (corresponding with the pitch cone of the blank), attached to the arbor and held by two flexible steel bands stretched in opposite directions, one end being attached to the cone and the other to a fixed part of the mechanism, thus preventing this cone from making any but a rolling motion when the arbor receives the conical swinging motion. In the engraving, *A* is the blank to be cut, *B* the ram carrying the cutting tool, and *C* the indexing and rolling mechanism.

TYPES OF GEARS IN AUTOMOBILES

Spur Gears. A spur gear is not only by far the most common kind of gear, but is also the easiest to describe, consisting, as it does, of a round flat disc with teeth cut in its circumference, i.e., around the periphery of the disc, as shown in Fig. 311.

Bevel Gears. Bevel gears, in which the shafts are at right angles and in the same plane or in the same plane but not at right angles, are more difficult to cut and are therefore less used. They are now cut, like the spurs, in an automatic or nearly automatic machine, which requires little attention, but which does require more care than the spur-gear machine. Both spurs and bevels sometimes require a chamfered tooth edge; spur gears as used in the Panhard, or clash-gear, transmission are always in need of it. This work was formerly done by hand, but now a special machine has been manufactured for this purpose.

There are no real restrictions against the use of the spur and bevel, either or both being used interchangeably. Very often they are used in combinations which appear peculiar, as the one shown in Fig. 311. This is the final drive and reduction gear of the Autocar commercial cars, made by the Autocar Company, Ardmore, Pennsylvania. In this gear, it will be noticed that the drive from the engine is through bevels to an intermediate shaft and that the final drive is by spur gears.

Helical and Herringbone Gears. In situations where quiet running is deemed necessary, the use of a helical gear frequently finds favor, since it accomplishes the desired result, although the cost of cutting is high. Of late, these gears have come into general use for camshaft drives and similar places. A pair of helical gears set so that the helices run in opposite directions forms a herringbone gear. This is even more quiet in its action than the single helix and possesses other virtues as well. One well-known firm has adopted it for camshaft driving gears and makes it as described to save cutting-cost, as the cost of cutting a true herringbone would be prohibitive. So a pair of helical gears of opposite direction are set back to back and riveted or otherwise fastened together, forming a herringbone gear at a low cost. Both of these may be used when the two shafts are par-

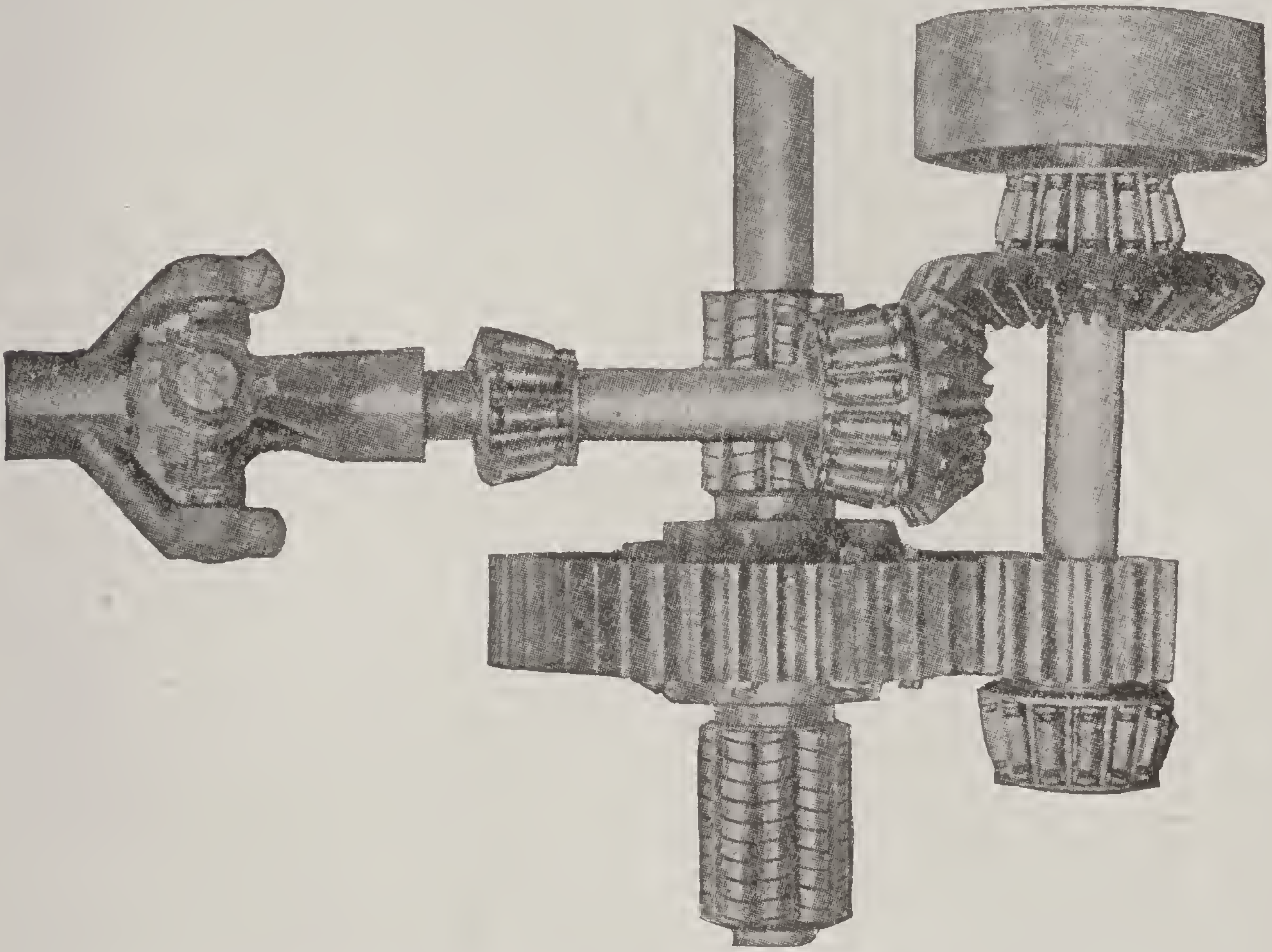


Fig. 311. Combination of Gears in the Autocar Final Drive

allel and in the same plane, but for all cases where the shafts are neither in the same plane nor parallel, some form of spiral gear must be made use of.

Spiral Gears. Spiral gears, as such, are not generally understood, but that variety of the spiral known as the *worm* gear is very simple and easily understood and it has attained much popularity within the past few years. This popularity has been due, in part, to superior facilities for cutting correct worms and gears, but, in the main, to a superior knowledge of the principles upon which the worm works and of the things which spelled failure or success. Thus, one of the earliest experimenters in this line laid down the law that the rubbing velocity should not exceed 300 feet per minute if success was desired or in rotary speed about 80 to 100 revolutions. For automobile use, this was out of the question; but later experimenters found that these results only attached to the forms of gear used by the early workers and did not apply to a strictly modern gear laid down on scientific principles.

The mistake made was in the pitch angle of the worm, which was formerly made small, nothing over 15 degrees being attempted. This was the item that was at fault and that caused this very useful and efficient mode of driving to fall into disuse. As soon as this fact was ascertained and larger pitch angles utilized, better results were obtained, until, with 20-degree angles, 700 feet per minute pitch-line velocity was attained, followed shortly by the use of even higher angles, resulting even more successfully. As the efficiency depends directly upon the pitch angle, these changes brought the efficiency of this form of gearing from the former despised 30, 40, and sometimes 50 per cent up to 87, 88, and even 90 per cent, thus putting it on a par with all but the very best of spur gears and above bevel gearing. In fact, in the light of modern knowledge of worm gears, it could easily be said, without departing from the truth, that it is possible to obtain from this form an efficiency of 93 per cent. In automobile work, the worm gear has been used mostly for steering gears and final drives. In the former, its irreversible quality is brought out, while in the latter, this quality must be made subordinate to a great reduction, which may be attained in a very small compact space. Many modern machines make use of worm gears. Some of the users are: the Jeffery, Baker, Detroit, Hupp-Yeats, and

Woods electrics; Pierce, Packard, Riker, Mack, Atterbury, Blair, Chase, Gramm, G.M.C., Hulburt, Moreland, Standard, Sterling, and other trucks; Dennis (English) busses and trucks and Greenwood and Batley (English) trucks.

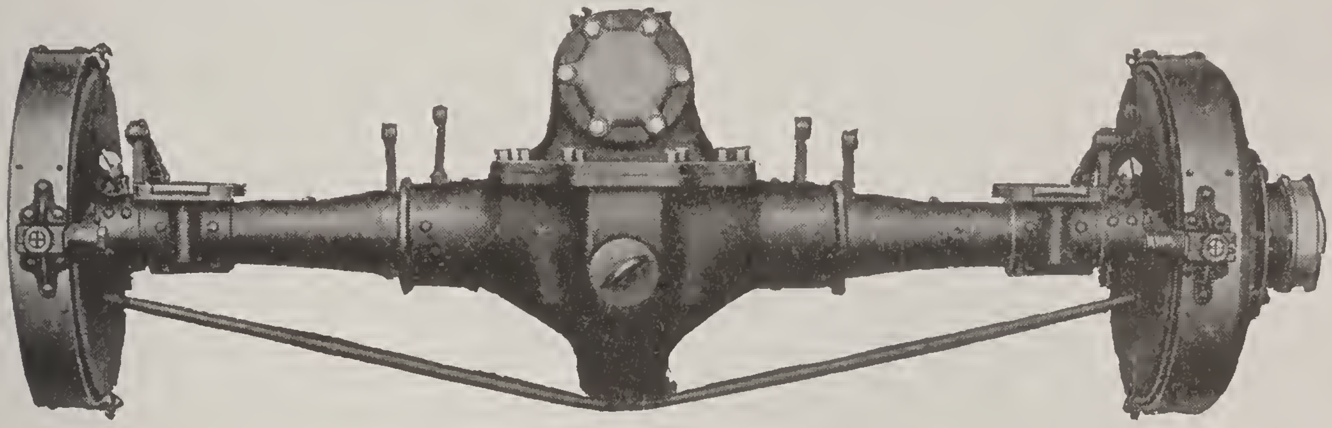


Fig. 312. Rear View of Timken Worm-Driven Rear Axle
Courtesy of Timken-Detroit Axle Company, Detroit, Michigan

Spiral Bevels. The spiral bevel is a new development, having been brought out in 1914 as a compromise between the worm and the straight bevel. As such, it is supposed to have practically all the advantages of both, except that it does not afford the great speed

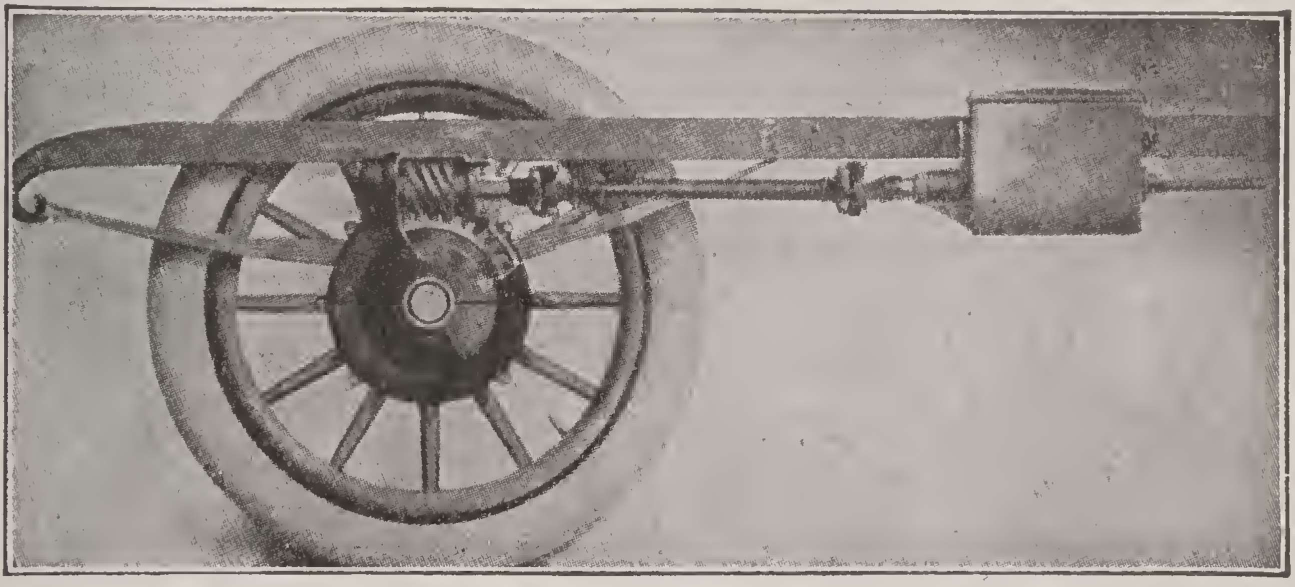


Fig. 313. Worm Gear Applied to Rear Axle Drive of Touring Car

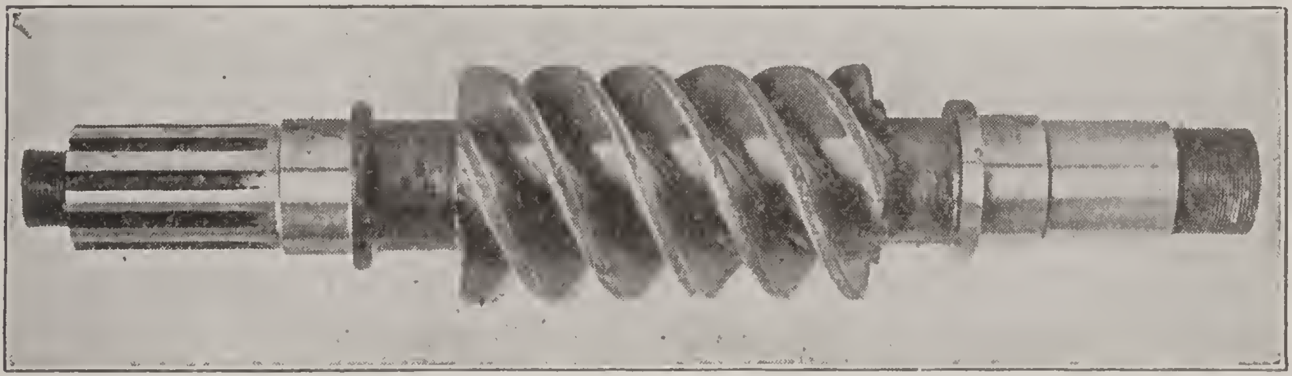


Fig. 314. Worm Used on Locomobile Trucks
Courtesy of Locomobile Company of America, Bridgeport, Connecticut

reduction that can be accomplished with a worm in the same space, being more like the bevel in this respect.

Among those using the spiral bevel are the Packard, Cadillac, Reo, Stearns-Knight, Velie, Kline, Apperson, Buick, Chalmers, Chandler, Cole, Haynes, Hupmobile, Jackson, King, Locomobile, and many others. Figs. 312 and 313 show applications of the worm; Fig. 314, a detail of the worm as used on a prominent truck; and Fig. 315, a detail of the spiral bevel as used on a prominent car.

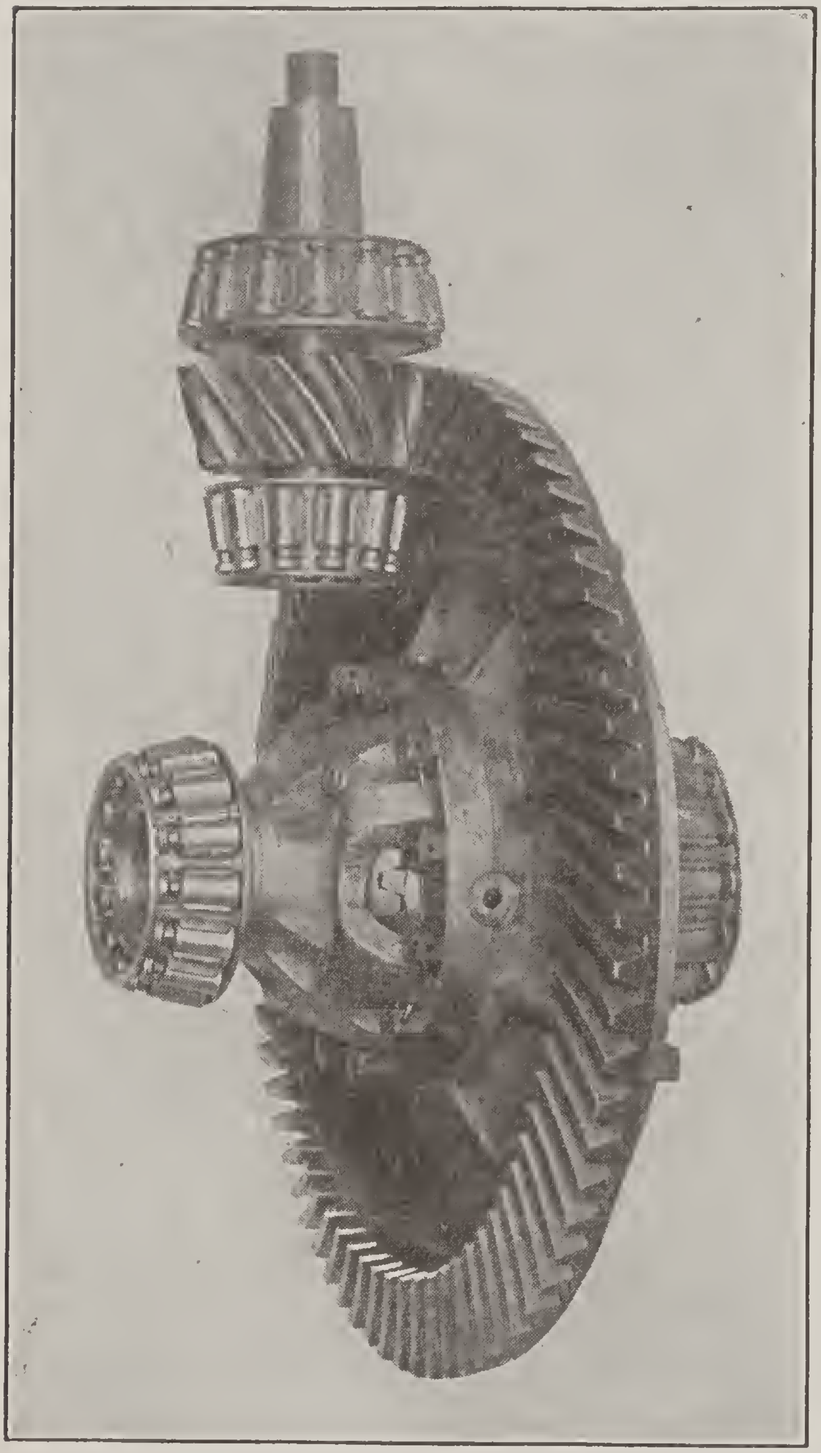


Fig. 315. Cadillac Helical-Bevel Driving Gear and Pinion

Worm Gears. Progress in the application of worm gears for rear-axle use has been considerable in the last few years. In one respect, at least, designers have found it an advantage. The top position for the worm was not much used at first, as it was thought impossible for it to receive sufficient lubricant there. Consequently, it was always placed in the bottom position, which cut down the clearance considerably; in this position the clearance was less than with the ordinary bevel. With the proof that the worm could be lubricated in a satisfactory manner in the top position, the majority of gears are so placed, thus converting what was formerly a disadvantage into an advantage, for in the upper position the clearance is greater than with bevel gears. This is shown quite clearly in Fig. 312, where it will be noted that the worm-gear housing in the center is actually higher than are the brake drums at either end of the axle. This, too, despite the fact that a truss rod passes beneath the center of the axle. For heavy trucks, especially, and for electric pleasure cars, the worm has proved an ideal drive. In these situations, there is the condition of high-engine or electric-motor speed, coupled with low-vehicle speed requirements, which necessitate a considerable reduction. As pointed out, the worm gives this in a small space.

For 1916, the very apparent tendency in final drives is toward spiral bevels for pleasure cars and worms for electrics and trucks. The tendency toward spirals is very great, amounting practically to a landslide, 57 per cent using it against 10 for 1915. The development of special machinery for cutting these gears and the understanding of their use has brought this about. In the truck field there has been a similar movement toward the worm, due to similar causes.

Gear Pitch and Faces. The manufacturers of transmissions and of gears for them do not agree as to the best gears. Neither do they agree as to which gears are most quiet or most efficient. In general, coarse-pitch stub-tooth gears are gaining faster than any other form. The 6–8 pitch is fairly general for gears of $\frac{3}{4}$-inch and $\frac{7}{8}$-inch face, and 4–5 pitch for wider gears. One manufacturer, Warner, considers the finer pitch gears and narrower faces as less likely to make noise, since they will not distort as much in hardening as wider gears. In this, other manufacturers agree, but there are some who claim to have had both quiet and noisy operation with both fine and coarse pitch. The tendency toward compactness has not increased transmission-gear faces any appreciable amount, nor has the increased use of better steels and better hardening processes lessened the size of the four noticeably.

Gear Troubles. Most of the common gear troubles have been previously covered at the end of transmissions. There is not as much trouble with gears today as there was several years ago. This is due to better design, better materials, better processes, and better assembling on the part of manufacturers and to more skill in handling, caring for, and adjusting on the part of owners. Of course, the repair man still finds plenty to do, but the percentage of gear repairs is relatively less than ever before.

SUMMARY OF INSTRUCTIONS

CLUTCHES

Q. Why is a clutch needed?

A. The clutch is needed to disconnect the rest of the drive from the engine. The gasoline engine cannot start under a load but must first get up speed. By means of the clutch, which can be thrown out, the engine is allowed to run alone and get up the necessary speed, then the load or drive can be thrown on. This is just as true of the stationary gas engine as of the automobile, motor boat, or aeroplane power plant.

Q. How does the clutch act?

A. It is designed and constructed so that the amount of friction surface, with the spring pressure provided, is sufficient to transmit the whole power of the engine (and slightly more as a factor of safety) when the clutch is in. In addition, it is so designed and constructed that when the clutch is out the spring pressure is taken up in such a way as to be self-contained, that is, its thrust is carried to a member outside of the clutch itself which is able to withstand this thrust. In this way, when the clutch is out, the engine is entirely free, and when the clutch is in, the connection is such that it will carry more than the maximum power of the engine.

Q. To what type of clutch does this apply?

A. This applies to all clutches, regardless of type or design, with the single exception of clutches on traction engines or on agricultural tractors. These are designed in the same way but work just the opposite, being engaged only when the clutch pedal is pressed and disengaged when it is released. On this account, the clutch is arranged so that it can be set to be *in* all the time or *out* all the time. With this exception, the arrangement described applies to all internal-combustion engines, although clutches vary widely in type, size and arrangement.

Q. What are some of the most popular forms of automobile clutches?

A. The multiple-disc and the cone divide honors; and there are a few expanding- and contracting-band forms and some miscellaneous types. The first two included almost 94 per cent of the total in 1914, over 95 in 1915, and almost 97 in 1916.

Q. What are the two divisions of the cone form?

A. The cone form is made in two ways, the direct form and the indirect form. The direct form has the cone introduced directly into the flywheel, which is tapered inwards for this purpose. This makes it a very simple device to construct, the machining of the flywheel forming the female portion of the clutching surface. The indirect form, or inverted cone, differs in that the female portion is made as a separate flange bolted to the flywheel and tapering outward. The cone is placed inside of this, so that it works *out* against the clutching surface instead of *in* against this surface, as in the direct type.

Q. What are the relative advantages of the two forms?

A. The indirect is little used now, although it was popular years ago. The extra bolted-on inverted cone adds to the flywheel weight, for it is large and heavy and gives considerable flywheel effect. However, the flywheel is simplified. The spring is enclosed between the flywheel and the cone, this being considered an advantage in the early days but now considered a disadvantage because it is inaccessible for inspection or adjustment. The cone is pushed in—away from the clutching surface—to disconnect it, while on the more simple direct type, the cone is pushed out—away from the clutching surface—to disconnect.

Q. What are the divisions of the disc clutch?

A. Disc clutches are generally grouped according to lubrication, those which run in oil being called wet, and those which run without lubricant of any kind being called dry. In addition, a distinction is generally made between the disc clutch with a very few plates (one, two, or three), usually called a plate clutch, and the form with many plates (10 or more) which is called a multiple-disc clutch. Either plate or multiple form may run wet or dry.

Q. Explain the difference between the wet and dry multiple forms.

A. In the wet form, the plates, or discs, are plain steel and are submerged in oil, the entire clutch housing being filled with oil. The clutch discs work steel face against steel face, the action of the spring when the clutch is let in gradually squeezing out the oil from between the faces. This gradual squeezing out of the oil gives this form its gradual-application quality, for with six or seven pairs of discs the squeezing-out process takes an appreciable length of time. In the dry form, the plates are ordinarily faced with a special clutching surface of woven asbestos fabric similar to brake lining, this being placed upon every alternate disc, that is, the actual clutching surfaces consist of steel and fabric alternating. The general method of construction is to take one set, say the inner discs, and face both sides of each one. Then none of the outer discs are faced, so that when the clutch is assembled there is a steel face against each fabric face. This form is run absolutely dry; in fact, considerable pains is taken in design and assembly to keep out any form of lubricant.

Q. Explain the difference between the plate and the multiple-disc forms.

A. In the multiple-disc form, a considerable number, say 11, 13, 15, or some such number of discs, is used; the smaller number, as 5, 6, 7, etc., being the driving, and the larger half, as 8, 9, 10, etc., being the driven. In the plate form, a very small number of plates of the largest size which the flywheel will allow is used. As a rule, the flywheel inner surface is machined out to form one of the surfaces, the engaging or disengaging member another, and a single disc between; or, perhaps, another large disc is fixed to the flywheel and two discs used between this and the other two surfaces. The plate form has the advantages of a small number of parts and of compactness; but, on the other hand, the discs are so large and heavy that assembling is not so easy and a considerable flywheel effect is produced. Moreover, it is not so easy to produce an absolutely flat surface in the larger sizes, for which reason the clutching is not so even and smooth. In the smaller sizes, no attempt is made at perfectly flat surfaces, as the inequalities balance one another.

Q. What is the general tendency in cone=clutch surfaces?

A. As to size, the tendency is toward larger diameters and smaller or narrowed clutch faces. As to materials, asbestos woven fabric is gradually replacing leather. Light springs under the fabric form the means of gradual engagement, corks going out with the leather with which they were used.

Q. What is the general form of the clutch spring?

A. Formerly, all clutch springs were of spring wire of the maximum possible diameter and, therefore, very stiff. The modern tendency is toward a distribution of spring pressure by means of a number of smaller weaker springs. The former method almost invariably called for complete enclosure, making adjustments and replacements difficult. The smaller springs are usually placed outside, so that they can be adjusted or replaced easily and quickly. It has been found, too, that by using a large number, say 6, 7, or more, distributed around the clutching surface, a much lighter spring pressure can be used with equally good effect. In fact, many modern cars have so light a clutch spring that it can be disengaged with one finger.

Q. How does the contracting=band clutch work?

A. It has two half-bands which the clutching mechanism draws tight against a drum. In effect, a contracting-band clutch is like a band brake, except that the braking band is in two halves and operates from the center instead of from the exterior surface.

Q. Is this a popular form?

A. No. It is rapidly going out of use; only one or two American cars, with perhaps the same number in Europe, are now using it.

Q. How does the expanding=band clutch work?

A. In a somewhat similar manner to the expanding, or internal, brake; that is, it has two segments of fairly stiff metal section, which the movement of a cam, or expander, presses outward against the inside of the clutch drum (or inside face of the flywheel). This cam, or expander, is worked by the movement of the clutch pedal, or spring—outward so as to expand the band and take hold of the drum for engagement; inward so as to allow the band to contract.

Q. Is this type gaining in popularity?

A. No. On the contrary, it is losing so rapidly that there are practically no cars built in this country with it, although a number of old cars with this form are still running.

Q. What is the usual position of the clutch?

A. Within the flywheel. This saves a great deal of space, a number of parts, and considerable weight.

Q. Why is this position used so freely?

A. Partly because of the savings just mentioned, and partly because of the rapidly growing use of unit-power plants which forces this location. With the engine and transmission as a unit and the necessity for the clutch being between them, the flywheel interior is about the only place for the clutch.

Q. How can the surface, and thus the transmitting power, of clutch discs be increased?

A. By the use of other than plane surfaces. Thus, in the Hele-Shaw form each disc is made with a small cone projecting from it. The outside of this engages with the interior of the cone on the next. Other forms have half-cone or other inclined surfaces and half-plane surfaces. As a straight line is the shortest distance between two points, so a plane flat surface gives the smallest area between any two points in parallel surfaces. From this it is apparent that any surface not plane offers a greater area than does the plane one. However, the plane surface is so much easier and cheaper to make, use, replace, etc., that it has gradually driven out all these forms with greater surface despite their advantages in the way of transmitting power.

Q. What causes a slipping cone clutch?

A. A slipping cone clutch is generally caused by oil, grease, or other lubricant on the clutching surface or by a weak spring.

Q. How can this be remedied?

A. The surface can be cleaned with kerosene, then with gasoline, and dried. Or, if the surface is glazed, it can be roughened by using a file. Or, if the slipping occurs out on the road and no tools are available, any powder or fine material which will give roughness can be used. It is possible to get home with a slipping cone clutch by de-clutching and forcing in some sand. Of course, this is not advisable, but it works in an emergency.

Q. What causes a disc clutch to slip?

A. In a metal-to-metal type, a burred plate or a weak spring or a very thin oil which can not all be squeezed out will prevent engagement. The two latter causes are easily remedied; the former means removing the clutch and taking it apart to find the plate which is burred or roughened. In a faced, or dry disc, clutch slipping may be caused by oil, grease, or other lubricant getting in on the surfaces or by a weak spring.

Q. What other things may cause a clutch to slip?

A. The pedal may be held out, when it appears to be in, by the emergency brake interlock, by a bent or twisted rod, by a rod which presses against something, by a tight-fitting pin in one of the connections, by a worn pin, or by a bent-clutch spider which cannot contact all over because of this bend.

Questions for Home Study

1. Describe in detail the construction of the Studebaker clutch.

2. Tell how you would adjust the Stearns-Knight clutch springs.

3. Give the method of removing and replacing a clutch spring in the Warner clutch.

4. If springs under the clutch facing of a cone clutch do not produce gradual engagement, what is the matter, and how would you remedy it?

5. How does the Cadillac clutch work?

6. How does it differ from other clutches of the same type?

7. How would you lubricate a clutch bearing, with what, and how often?

8. Describe a quick, easy method of replacing corks in a clutch.

9. How would you construct a device to hold clutch springs while replacing them?

TRANSMISSIONS

Q. What is the purpose of the transmission in a motor car?

A. To allow variations in the speed of the car forward from the lowest to the highest, and for reverse, without varying the motor speed greatly.

Q. Why cannot the engine speed be varied directly, doing away with the transmission?

A. The lowest speed used in cars ordinarily would not be possible with the present engine, since it could not be throttled down slow enough. Again, if the gearing were such as to give the present lowest car speeds with the engine low speed, then for maximum engine speeds the highest possible car speed would be very low. In short, gearing is necessary to give a greater variation than is possible with the engine alone. Further, reverse could not be obtained without additional gears and this would necessitate also a method of shifting the reverse gear into, and out of, mesh. Thus, all the requirements of the modern gear transmission would be necessary for reverse alone.

Q. Show by the use of figures the impossibility of doing without the transmission.

A. The circumference of 34-inch wheels is 136.8 inches, or 11.4 feet. With the engine geared direct to the wheels, the speed of the latter would be directly proportional to the former, considering the gear reduction. If an average present-day gear reduction of 3.8 to 1 be considered at 240 r.p.m., which is very low, the car would make

10.3 m.p.h. as its lowest possible speed. And at 2400 r.p.m.—a high maximum for an engine with as low a speed as 240—the highest car speed would be 103 m.p.h. As the average roads would not allow this high a speed, and as the average car has a low speed approximating 3 m.p.h., it is apparent that the gear ratio is too high. By lowering this to 12 to 1 at a low speed of 264 r.p.m. of the engine, a low car speed of 2.85 m.p.h. would be obtained. And with 2640 r.p.m. as the highest engine speed, the highest car speed would be only 28.5 m.p.h. From these two extremes, it is apparent that direct gearing without a transmission is not feasible.

Q. What are the general classes of transmission now in use?

A. There are five general classes: sliding gear, individual clutch, planetary, friction, and miscellaneous types. The first named is most popular and constitutes perhaps 90 or more per cent of all the cars now built. The individual clutch is really a modification of the sliding gear, but is not widely used—not to exceed 3 or 4 per cent. The planetary is the most simple form to operate but, unlike the others, is limited as to the number of possible speeds. Practically the only American maker using this today is Ford. The friction form was intended to give a maximum number of speeds with maximum simplicity. It does this, but other faults offset these advantages. Metz is about the only American car-maker using it regularly. The miscellaneous transmissions include what might be called the unproved inventions—forms which have not been tried out sufficiently to be proved successes. Consequently, this class is small. It includes hydraulic, electric, magnetic, and various other forms of transmissions.

Q. What is the average number of speeds?

A. Three is the most popular number, four is found on a number of high-class cars, the planetary can give but two, the friction form may give five or more, the only magnetic form on the market gives seven. In general, three is considered sufficient; even the highest-priced makers are gradually giving up the use of four-speed gear boxes, and the number of these is less each year.

Q. What are the three methods of gear shifting now in use?

A. The selective accounts for about 94 per cent, the progressive form is not used by more than 2 or 3, and electric shifting is used by but two makers.

Q. How does the selective form work?

A. The operator is at liberty to select any gear he desires and to go directly to that speed from the speed which he is using. This means with common sense reservations; for instance, it would be foolish to go from high to reverse, although this is possible in this form.

Q. How is this accomplished?

A. Within the gear box, the gears are shifted by forms, and the quadrant arrangement is such that the driver can shift his lever so as to pick up the fork which will give the desired speed. Usually there are but two shifting members (in the three-speed form), one giving low speed and reverse, the other intermediate and high. Having picked up the low and reverse fork, he can shift his lever forward for low and backward for reverse; similarly, with the other fork for second and third speeds.

Q. How does the progressive form work?

A. In this type of gear box, the speeds must be used in succession—first the low, then second, then high, and when slowing down from high, to second, then low, then reverse. For instance, if driving in high and a turn is passed in a narrow road, it would be necessary to shift down to second, then to low, then to reverse. The driver could now back his car past the street into a position which would enable him to make the turn. Then he could speed up the car again by using first low speed, then second, and finally high. This maneuver could not be accomplished in any other way. In the same circumstances with a selective gear, the car could be brought to a dead stop with the brakes, an immediate shift to reverse effected, the car backed up, and the gears shifted to low and then high speed forward, thus doing the same thing as before with half as many changes.

Q. How is the high speed generally effected?

A. High speed in all modern transmissions is a direct drive so that none of the various gear reductions are in use. This method reduces the amount of noise by eliminating at once the meshing of two sets of gears, the average high-speed direct drive being effected by clutching one gear up to another.

Q. Is this arrangement always used?

A. No. In some four-speed gears the highest speed is a geared-up form, and the direct drive is used on third speed. This is done with the idea of securing the silence of the direct drive for all average rapid driving, while the geared-up form gives an extraordinary speed for emergencies where noise is immaterial.

Q. In the electric gear shifter, how is the movement of gears effected?

A. The shifter is made with a series of electromagnets, or solenoids, one for each speed and one for reverse. Current flows to these when the proper button is pressed. It is well known that when an electric current is passed through an electromagnet of the solenoid type, the rod, or bar, inside of it is drawn forward. This arrangement produces the speed corresponding to the button pressed. In actual practice, the current does not flow until the clutch pedal is depressed after the button has been pressed.

Q. Where is the transmission located?

A. Excluding freak forms, there are four general positions: in unit with the motor; amidships in unit with the clutch; amidships but separated from the clutch and in unit with the forward end of the driving shaft; and in unit with the rear axle.

Q. Are these same locations used on motor trucks?

A. Yes. Except that the third class is sometimes modified with chain drive, so that the transmission is amidships but in unit with the jackshaft.

Q. Which of these is most popular?

A. The form in which the transmission is grouped with the motor and clutch, that is, the unit power plant, is now the most popular, and the tendency among the makers is to make it more so. It is gaining at the expense of all other locations.

Q. What difference is noted in gasoline railway=car transmissions?

A. As all speeds must be used in the reverse direction, the design is so modified as to allow the driver first to choose the direction and then to utilize all his transmission speeds in that direction.

Q. What is the difference between individual clutch and other transmissions, particularly the sliding=gear type?

A. In the individual-clutch type, no one of the gears is fixed to its shaft, but an individual clutch is provided for each. The purpose of this is to clutch the gear to its shaft so that it can drive or be driven. When shifting gears, the driver moves the usual lever in the usual way, but within the transmission this lever, instead of moving a gear on a shaft to which it is keyed, moves a clutch which keys the desired gear to the shaft.

Q. What is the advantage of this over sliding gears?

A. In the sliding gear, the moving members must take the drive and transmit the power in addition to withstanding the shocks and destructive action of shifting or meshing. In the individual clutch form, the gears have only to transmit the power, while the individual clutches have only the shocks and destructive action of shifting.

Q. How are gears pressed onto their shafts?

A. Usually by means of a hydraulic or a power press—one capable of exerting a pressure of many tons. Generally, it is easier to lay the gear out on the press table and press the shaft down into it, than the reverse.

Q. How are pressed-on gears removed?

A. The process of pressing on is reversed, and the gear is supported in such a way that the shaft can be pressed, or forced, out of it.

Q. How is the transmission removed from the chassis?

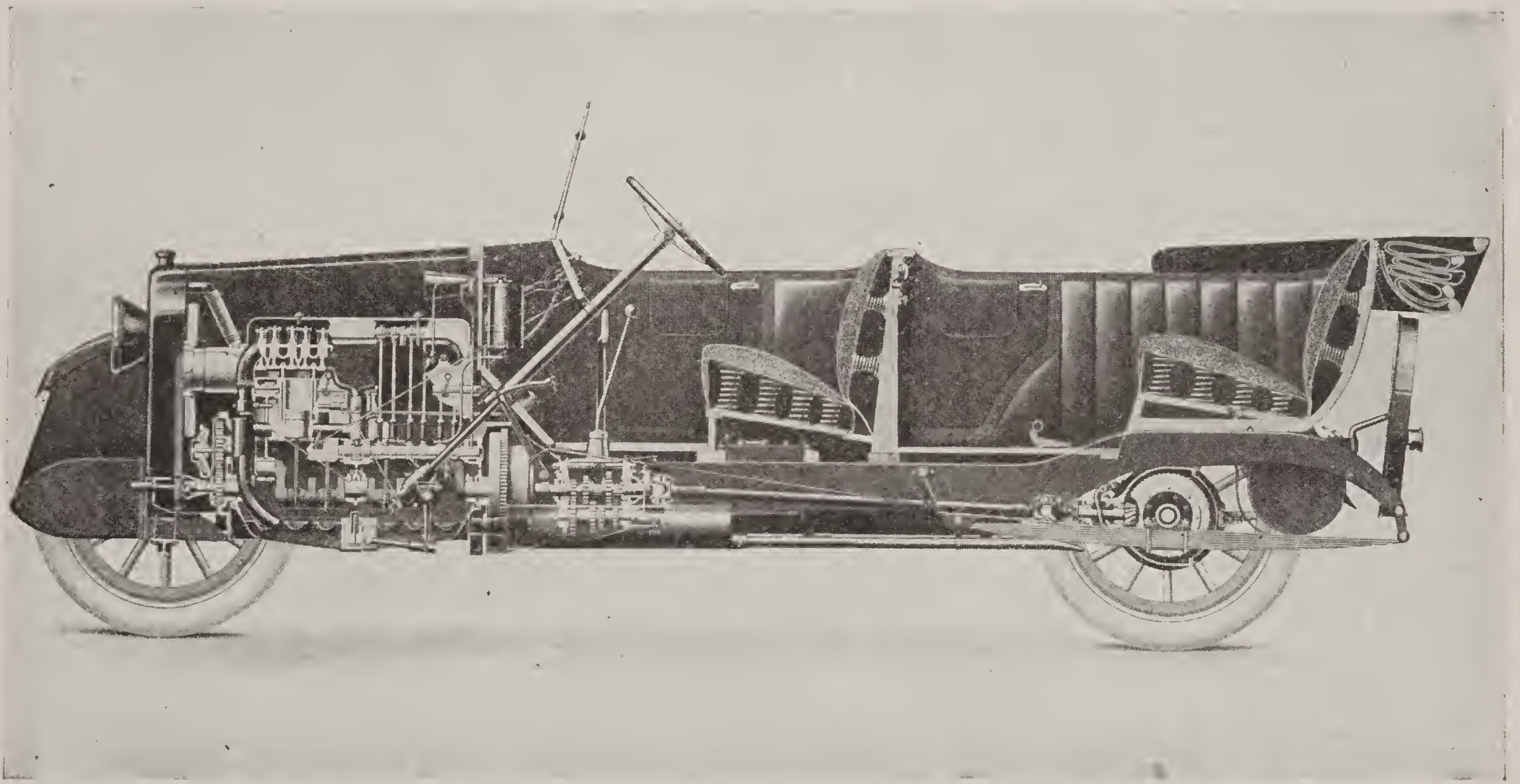
A. The usual method in well-equipped shops is to put a rope or chain sling or special cradle around the transmission, then to lift it vertically upwards by means of a block and tackle, electric or pneumatic overhead hoist, chain block attached to overhead tracks, or portable crane.

Q. How are bearings worked in?

A. After slow careful fitting by hand for both diameter and length, using a dummy shaft with dummy bearings, the real bearings should be put in place and run-in for several hours, using power from a line shaft. Transmission bearings should be run-in the same as engine bearings, set up somewhat tight and with an excess of oil.

Questions for Home Study

1. Describe the construction of the Cadillac and Winton transmissions, a railway transmission, the Mack truck, the Ford planetary, a friction form, and a magnetic type.
2. How would you adjust the shafts longitudinally in the Stearns transmission?
3. Tell how to construct a stand for gear pressing.
4. Give a thorough method of cleaning a transmission.
5. What are the usual gear pitches?
6. What is meant by the pitch of a gear?



SECTION OF NASH CAR, SHOWING ENGINE AND TRANSMISSION DETAILS AND REAR SPRING SUSPENSION
Courtesy of The Nash Motors Company, Kenosha, Wisconsin

GASOLINE AUTOMOBILES

PART V

STEERING GROUP

The mechanisms by which steering is effected are among the most important features of a car, if not actually the most important. The truth of this statement will be realized when attention is called to the fact that safe steering is the final requisite that has made the modern high speeds possible, for without safe and dependable steering gears, no racing driver would dare to run a machine at a high rate of speed, knowing that at any minute the unsafe steering apparatus might shift the control, thus allowing the front wheels to waver and the car to run into some obstruction by the roadside.

The same argument applies in an even greater degree to the case of the non-professional driver, who wants to be on the safe side even more, perhaps, than do the dare-devils who drive racing cars. Nearly all of our roads are curved and, to make all of these turns with safety, the steering gear must be reliable. Again, in mountainous country where there may be a sheer drop at the roadside of hundreds of feet, it becomes necessary that the steering mechanism be very accurate and that it obey, at once, the slightest move on the driver's part. To secure this accuracy, there must be no lost motion or wear of the interrelated parts.

These things mean that the whole steering mechanism must be safe and reliable; strong and accurate; well made and carefully fitted; well cared for; and finally, the design and construction must be based on a theoretically correct principle, for otherwise the mechanical refinements will have been wasted. Perhaps it will be more logical to treat the mechanical requirements first by showing how the present type has been evolved from the failures of earlier forms.

STEERING GEARS

General Requirements. In turning a corner a car follows a curve, the outer wheels obviously following curves of longer radius than do the inner wheels and, therefore, traveling farther. In straight-ahead running, the wheels run parallel at all times and travel the same distance. These two facts are the basic ones which make the steering action so complicated: First, that on straight-ahead running the wheels must travel the same distance; and second, that on turning curves the outer wheels, whichever they may be, must travel a greater distance.

This double requirement leads to the usual form of steering arrangement, called after its inventor, the "Ackerman". It was Ackerman who brought out the first vehicle in which the front wheels were mounted upon pivoted-axle ends, these ends being pivoted on the extremities of the central part of a fixed axle, while the pivoted ends carried one lever each. These levers were connected together by means of a cross-rod, while at one end another rod was attached, which was used to move the wheels. By moving this latter rod, both wheels were compelled to turn about their pivot points, since the cross-rod joined them together, and if one moved the other had to move also. This was Ackerman's substitute for the fifth wheel which had been used up to that time and is even today on all horse-drawn vehicles.

Inclining Axle Pivots. The situation is further complicated by the fact that the ideal arrangement, that is, the fixing of the steering pivot at the center of the turning wheel in order to allow the maximum turning movement for the minimum motion of the hand, is not suitable for general use. In practice, however, it is placed as close to the ideal position as possible, which, in the ordinary case, is within three to six inches.

This approximation to the ideal has been made by inclining the stud-axle pivot inward, so that its center line prolonged would strike the ground at a point coincident with the center line of the tire. This same result is also brought about by inclining the stud axle itself downward. The construction gives added safety, in that the force of head-on collisions is supposed to be delivered at or near the line of incidence.

The axle-spindle center may be brought close to the wheel hub by means of a double yoke, but this was tried and abandoned as too cumbersome for the results effected. A method of placing the steering pivot in the center of the wheel was also developed. In this case the pivot was enclosed in a hollow hub; but as this made the pivot, which is liable to wear, inaccessible, it also was abandoned. However, later tendencies point toward a revival of this construction.

The result is that today we are using a form which, though far from being ideal, fulfills every practical requirement. This form is usually constructed as in Fig. 316, which shows a skeleton plan view of an automobile. In this, the line *AB* represents in length, position, and direction, the front axle of a car, while *ML* represents in a similar manner the rear axle. *A* and *B* also are the pivot points for the axle-stud ends or, as they are more commonly called, the steering knuckles or steering pivots, which are represented by the lines *AD* and *BC*.

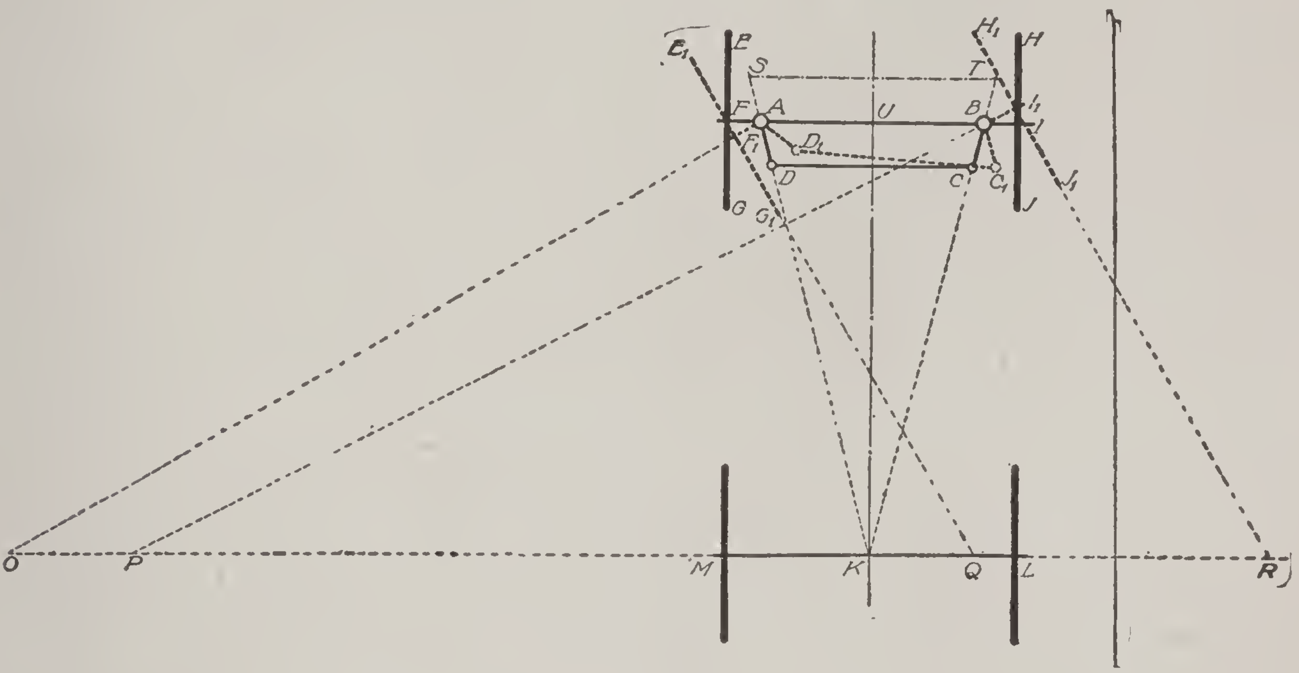


Fig. 316. Diagram of Steering Connections

The rear (or front, as the case may be) ends of the steering knuckles are joined by the connecting rod *DC*. The Ackerman construction is such that the center lines of the steering arms, or levers, *AD* and *BC*, prolonged, must pass through the center point of the rear axle at *K;* the reason for this is that the front wheels are supposed to turn about the center of the rear axle as a center.

Action of Wheels in Turning. If the wheels are supposed to turn through an angle, the action of the above arrangement will be seen. Suppose the steering gear (not shown in Fig. 316) is turned so as to move the steering lever *AD* to the new position, shown dotted at AD_1. This movement will also move the other lever *BC* to a new position, shown dotted at BC_1. It will be noted in this position that the angle through which the right-hand lever *BC* has swung is not as great as that through which the left-hand lever *AD* has moved, although the two levers are attached together by means of the cross-connection *DC*.

The wheels are mounted upon the extremities of the steering knuckles at *F* and *I*; *EG* represents the left wheel, and *HJ* the right wheel. These turn about the pivot points *A* and *B*, with the movement of the steering knuckles to the new positions, shown dotted at $E_1F_1G_1$ and $H_1I_1J_1$. In this position, prolongations of the lines through the pivot point and the center of the two wheels will meet the rear-axle center line prolonged at separate points as *OP*, the two lines converging slightly. This same convergence may be noted by prolonging the center line of the two wheels E_1G_1 to *Q* and H_1J_1 to *R*. This divergence means that the two wheels are turning on curves of different radii, and since the outer wheel H_1J_1 shows a longer distance from its center line prolonged to the rear-axle line *OPMKL* than does the inner wheel, that is, has the longer false radius, PI_1 being longer than OF_1, it follows that the turning action will be correct.

This is somewhat complicated and rather hard to follow, but the figure seems simple and should be examined closely, even drawing it out step by step, as outlined above, for the purpose of making the steering action clear. Laying this out for one's self will bring out the reason why the steering knuckles do not move through the same distance and thus bring about a different movement of the wheels.

Steering Levers in Front of Axle. That the final movement of the wheels will not be changed if the levers, Fig. 316, are laid out in the same way but in front of the axle will be evident by prolonging the levers to *S* and *T*, respectively, making the lengths *AS* and *BT* the same as the former lengths *AD* and *BC*. Connecting the two by the rod *ST* completes the front arrangement, which is seen to give the same results as the other. The choice of a front or rear location depends upon certain things, such as the safety of the cross-rod, etc., which will be brought out later on. Some machine manufacturers even go so far as to fit both front and rear levers to the same machine.

While shifting the lever from rear to front in Fig. 316 does not change the result at all, in Fig. 317 it does. In this construction, known as the Davis, the steering levers are set in front, but taper inward instead of outward, so that their center lines prolonged meet the center line of the car prolonged at a distance from the front axle equal to the distance between the front and rear axles, or equal to the wheel base.

In addition, the connecting rod is carried in guides placed on the front of the axle, so that its path of travel is always parallel to the front axle. Consequently, the levers must be made slotted or telescopic. The result of this combination of movements is an absolutely correct angle to both wheels for any angle of lock. This can be explained by a reference to the diagram.

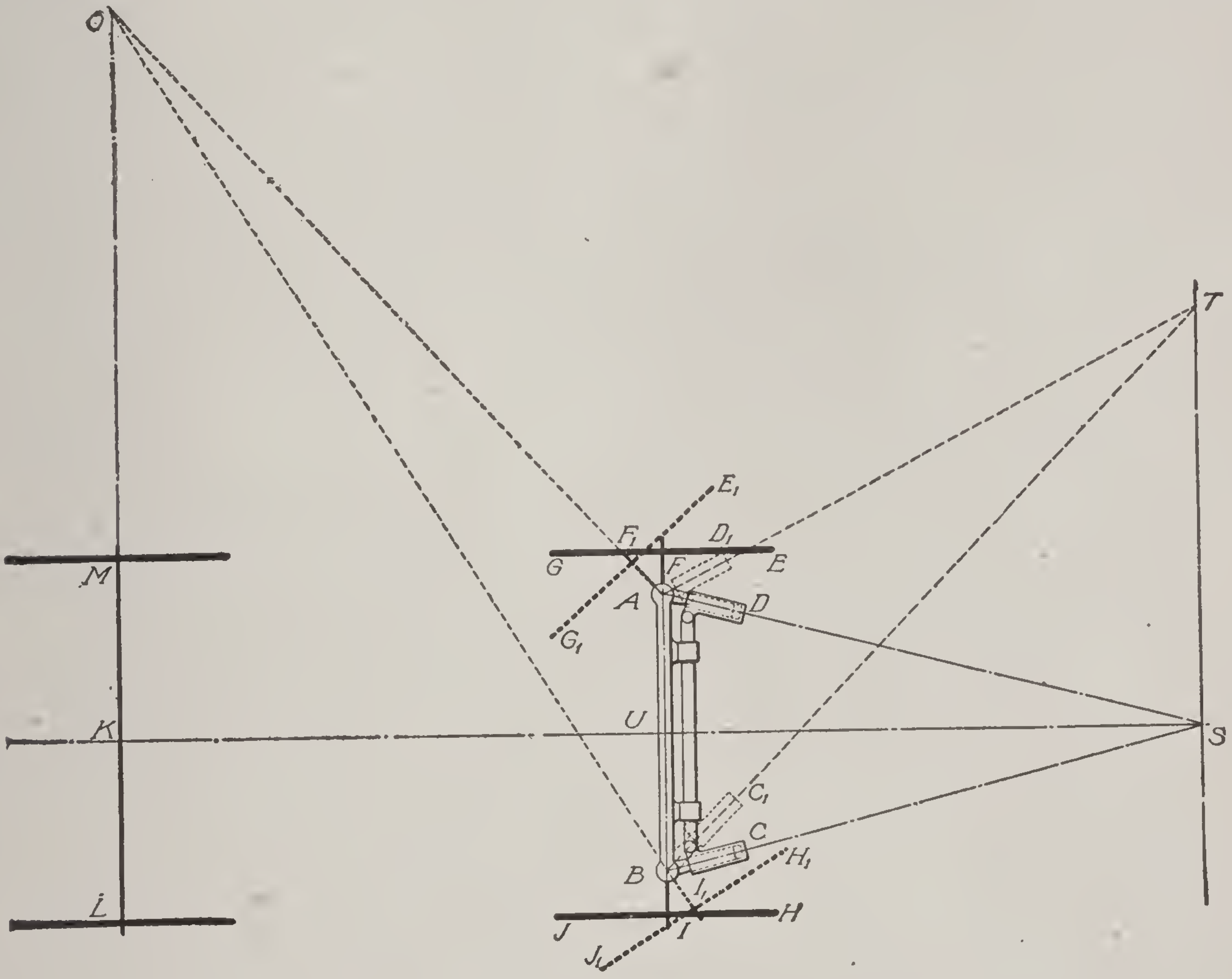


Fig. 317. Patented English Steering Device, Said to be Theoretically Perfect

In Fig. 316 the prolongations of the wheel center lines, or radii of turning, do not strike the center line of the rear axle—about which they are supposed to turn—at a common point, the difference being the amount they are out of true, viz, the distance between the points *O* and *P*. If Fig. 317 be lettered to correspond with Fig. 316, the prolongations of the knuckle center lines AF_1O and I_1BP in Fig. 316 become the two converging lines AF_1O and I_1BO meeting at the point O on the center line LMO of the rear axle prolonged. This is as it should be and shows the case of correct steering and turning.

In this case, all four wheels are turning about the point O, the two rear wheels with the radii OM and OL, and the two front wheels with the radii OF_1 and OI_1, respectively. This gives a theoretically correct case in which all wheels will round any curve as they should and not slip or slide around, damaging the tires in the process. The Davis type of steering gear, it may be remarked, is not in general use, its construction adding a number of parts to the more usual form, shown in Fig. 316, which gives close enough results for average use.

Like the sliding-gear transmission, a steering gear is a form of mechanism which, although used on nearly all automobiles, is, from a theoretical and mechanical standpoint, far from what it should be.

General Characteristics of Steering Gears. *Standard Types.* The movement or deflection of the front road wheels is obtained by a crosswise movement of the tie rod which links the steering-knuckle levers attached to the wheels. This tie rod, sometimes referred to as the cross-connecting rod, is actuated by the drag link GF, Fig. 318, which is pivotally mounted on the steering-knuckle lever L. The drag link has a linear movement along the frame and is parallel with it.

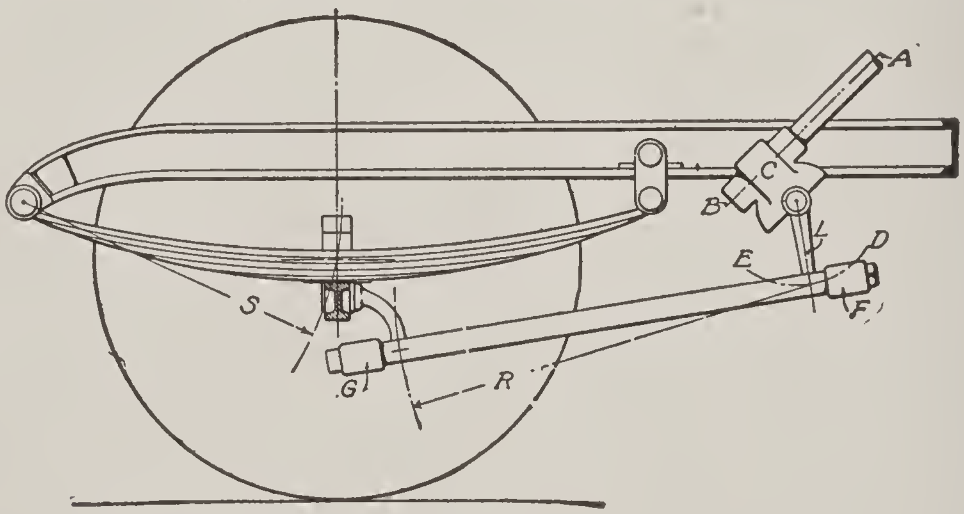


Fig. 318. Typical Steering Gear and Connections to Front Axle

The drag link is also pivotally mounted at the ball arm of the steering gear C, and when the drag link is moved forward or backward by movement of the ball arm, the tie rod is moved at right angles, deflecting the wheels. The drag link has a semi-rotary motion; that is, its upper end is turned through a part of a revolution while its lower end, to which the drag link is attached, swings through a fairly large arc, according to the capacity and design of the steering gear.

As the ball arm swings through its arc, the drag link attached to it rises and falls slightly, the movement being indicated by the dotted lines in Fig. 318. The partial circular motion in a vertical plane is converted from the rotation of the steering gear in a horizontal plane by several methods. The gear shown in Fig. 319 is known as the worm and sector type, which is illustrated in Fig. 318.

In Fig. 319 the steering column or post *CD* carries a worm *F* which is in mesh with the gear *E*. Rotating the column *CD* in the direction indicated by the arrows, or counter-clockwise, will result in the worm turning in the same direction. The gear *E* will rotate on its horizontal shaft in a downward movement, as shown by the arrow, and as the ball arm, or lever, is attached to the shaft, the member *L* will move backward, or to the left, as shown by the arrow intersecting the ball. With the worm type the two gears are usually in two different planes at right angles to each other, one vertical and the other horizontal. This is an advantage in that it lends itself readily to the construction of a simple steering-gear system. Thus the post is in a vertical or modified vertical line, as is also the motion of the steering arm, and the consequent movement of the steering rod is more or less confined to a vertical plane. With the worm and gear this is obtained in a simple manner. The gearshaft is in a horizontal plane passing through the center line of the worm. If the worm rotates in a direction which approximates a horizontal circle around a vertical axis, the worm gear will turn in a vertical plane about a horizontal axis. A lever attached to the end of this shaft will, consequently, move in the desired

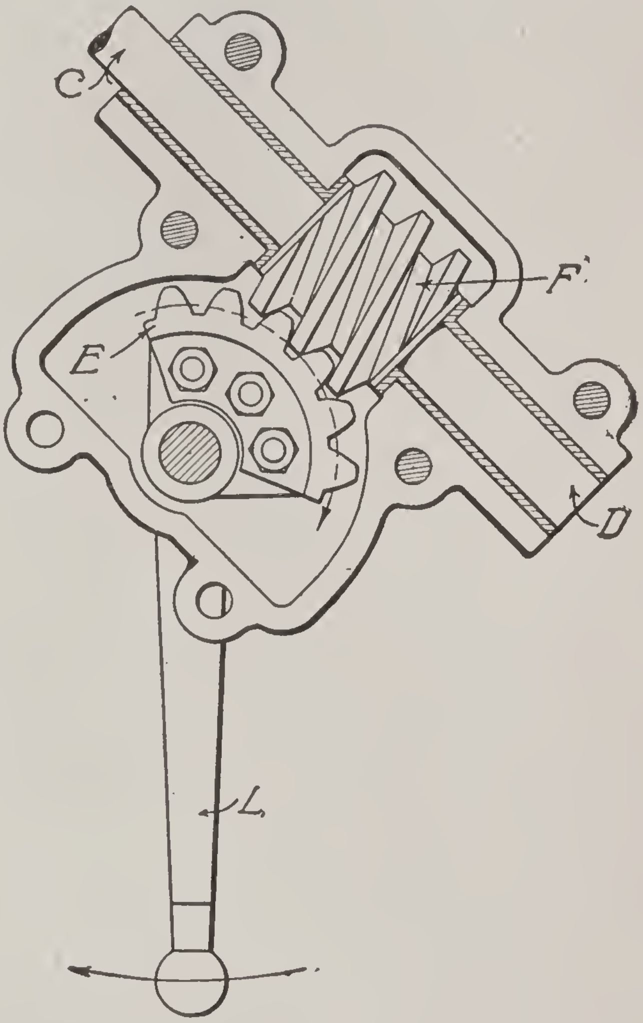


Fig. 319. Worm and Partial Gear of Typical Steering Gear

plane—the vertical one mentioned before—and the desired requirements are met.

The conversion of rotary motion in a horizontal plane to partial rotation in a vertical plane is shown in Fig. 320, the action here being slightly amplified. The steering, or hand, wheel *A* with spokes *B* is turned to the left, turning the steering column *C* (a hollow tube) in the direction indicated by the small arrow. *D* is the steering gear with its ball arm *E*. The turning of the hand wheel moves the ball end *F* and drag link backward. The front end of the drag link is attached to the steering knuckle *M* at *H* and turns about the center line *KL* of the steering knuckle *J*, the end turning through the arc *HI*. The lever *M* is attached to the knuckle *J* and turns with it. Its end turns through the arc *OP*, moving the tie rod *OQ* to the right and turning the other knuckle in the same way and direction. *YY* are the spring pads and *ZZ* the tapered roller bearings supporting the road wheels.

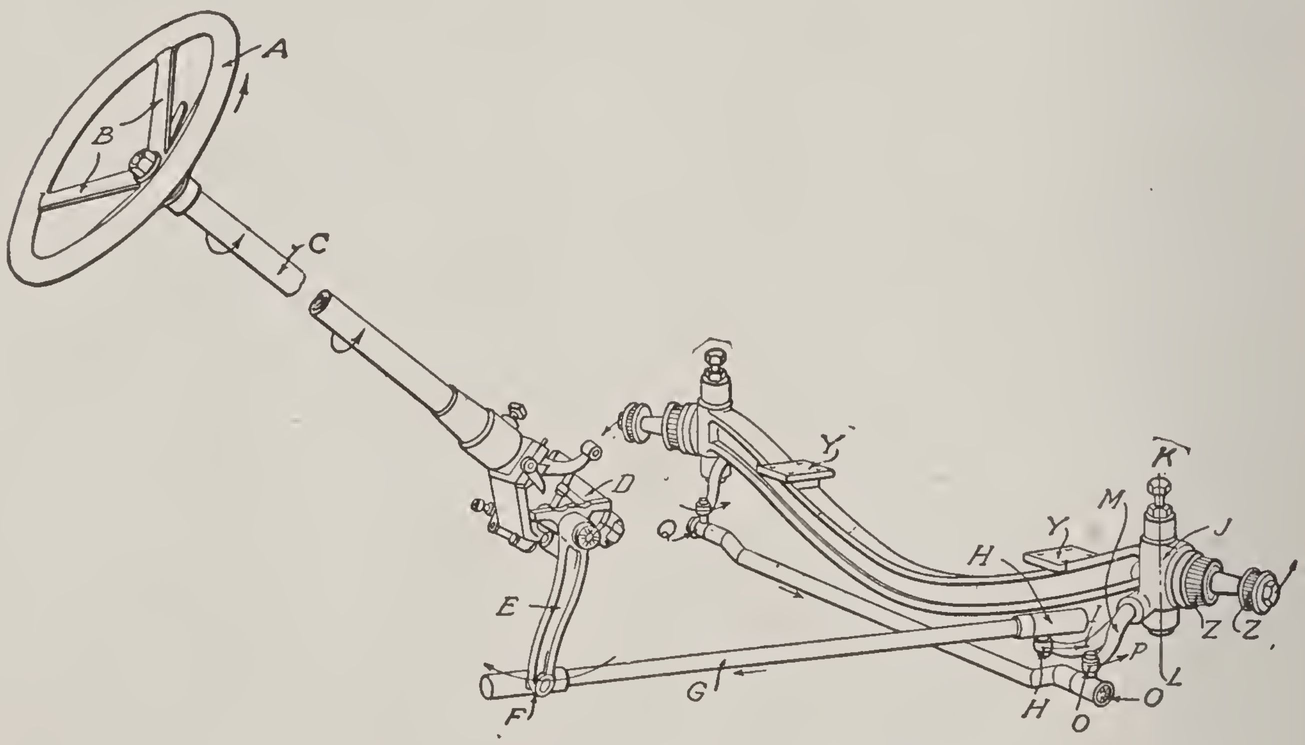


Fig. 320. Steering Mechanism and Front Axle of Pierce-Arrow Car
Courtesy of Pierce-Arrow Motor Car Company, Buffalo, New York

Classification. There are three general forms of steering gears: the worm, the bevel, and the spur. These may be subdivided, which might lead one to assume that there are a dozen or more different forms. The mechanical lever has been discarded because of its tendency to impart all road shocks to the driver; it is fully reversible at all times. Irreversibility is employed because it transmits to the road wheels any turning movement imparted by the driver without reversing or carrying back to the operator the original movement of the road wheels.

Many attempts have been made to substitute another form of mechanism for steering gears; this consists of various rod, lever, chain, and spring combinations. All of these have failed, however, because they lacked the fundamental requisite of irreversibility.

Aside from the many schemes mentioned which seek to avoid the use of the regular gear in the standard manner, there have been a number of unsuccessful attempts to avoid its use in other ways. Fig. 321 shows some of the gears which have been tried. At *1* is seen a device in which the rotation of a large bevel gear turned a small bevel pinion, the rotation of the latter serving to screw a long straight lever with a threaded inner end into or out of the interior of the threaded bevel pinion.

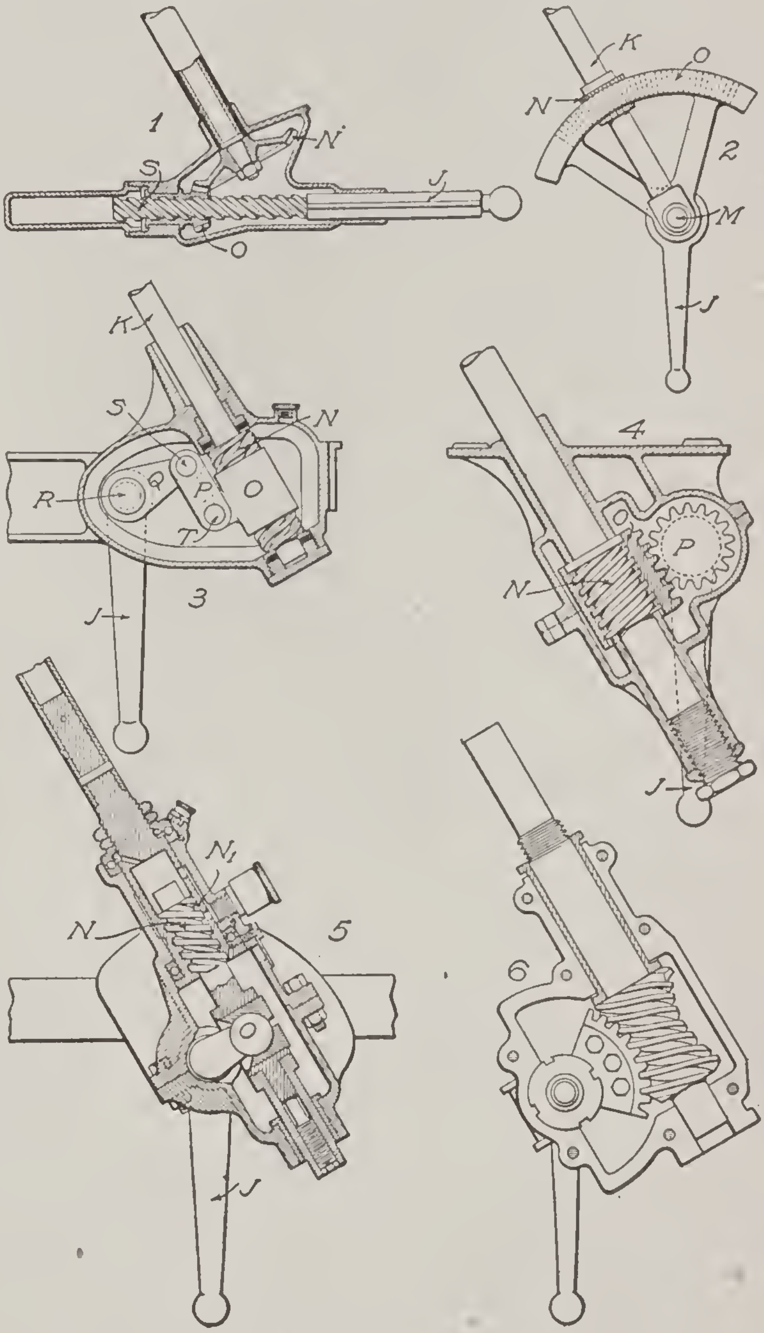


Fig. 321. Obsolete Forms of Worm Steering Gears

In the figure, *N* is the actuating bevel turned by the movement of the operator's hands, while *O* is the smaller actuated bevel pinion. Within this is seen the worm end *S* of the lever *J*, the ball at the outer end being connected to the steering knuckle. Since the bevel alone lost a great deal of power in friction, while the worm arrangement and the sliding action of the lever in its bearings did likewise, the total effort to turn this must have been enormous. At *2* is shown another form, which is the double-bevel arrangement; a small bevel *N* attached to the steering post *K* turns the larger bevel *O*, which is pivoted at the axis *M* about which the lever *J* attached to the segmental bevel *O* turns.

A most peculiar arrangement is shown at *3*, this being a combination of a worm and nut, two levers and a steering arm, as well as a connecting link for the two levers. Turning the hand wheel turns the worm, which moves the nut up or down. Since the nut is connected by means of the link to the lever, the motion of the nut up and down is transmitted to the short lever; this, in turn, moves the long-arm, or steering, lever. In the figure, *K* is the steering post, *N* the worm, *O* the nut, *P* the connecting link pivoted at the two ends *T* and *S*, *Q* the short-arm lever, and *J* the steering lever, the two latter being integral and pivoted at the point *R*. At *4* is shown a combination of a double internal worm with a rack and gear. In this, the turning movement of the inner worm causes the outer worm to travel up and down. Upon the exterior of this outer worm is cut a rack which is meshed with the gear, its up and down movements turning the gear around and thus effecting the steering, the steering lever being attached to the gear. *N* is the internal worm, *O* the external worm with the exterior rack, *P* the gear which meshes with it and carries the lever *J* as a part of it. At *5* is shown a combination of a double worm with a double ball and socket arrangement. The turning of the outer worm N_1 causes the inner worm *N* to rise and fall, the lower end of this carrying a ball-and-socket joint *O*, the end of the ball being formed integral with the steering lever *J*, which also has a ball and socket attachment at the other end. At *6* is shown a steering gear which was tried and discarded, but which is now coming to the fore and bids fair to oust many other forms of gear. It is variously called a globular worm, helicoidal worm, or Hindley worm, the worm forming a curve closely approximating the curve of the gear with which it is to mesh. This gives a greater number of teeth in mesh at any one time, spreading the wear over a larger surface and thus lengthening the life as well as accuracy of the steering gear.

Spur and Bevel Types. The spur- and bevel-toothed construction of gears may be reversible, and these types are to be found on low-priced cars, as the cost of cutting the gears is small. The spur gears have straight teeth, the edges, or sides, of the teeth being straight and parallel with the axis of the shaft on which the gear turns. In bevel gears the teeth taper toward a point and are inclined to the axis of the shaft. Another construction is the spiral gear. Both types may be made reversible and irreversible as desired.

Worm-Gear Types. With a very few exceptions, automobile engineers favor the worm type of steering gear, and it will be found on the highest priced cars. It has the advantage of being irreversible and is utilized in several forms. In the worm class of gears, some types are closely related, while others vary widely. For example, the complete sector and gear type differ only in that the wheel operated by the worm makes a complete circle or part of a circle. The full gear can be turned through 90 degrees and replaced on the shaft without presenting a new surface to the worm. Some hold that the worm must be subject to some wear, especially where it is most used. They contend that turning over the pinion brings new teeth to engage with the worm and that these teeth will not mesh properly when turned at an angle of from 20 to 30 degrees.

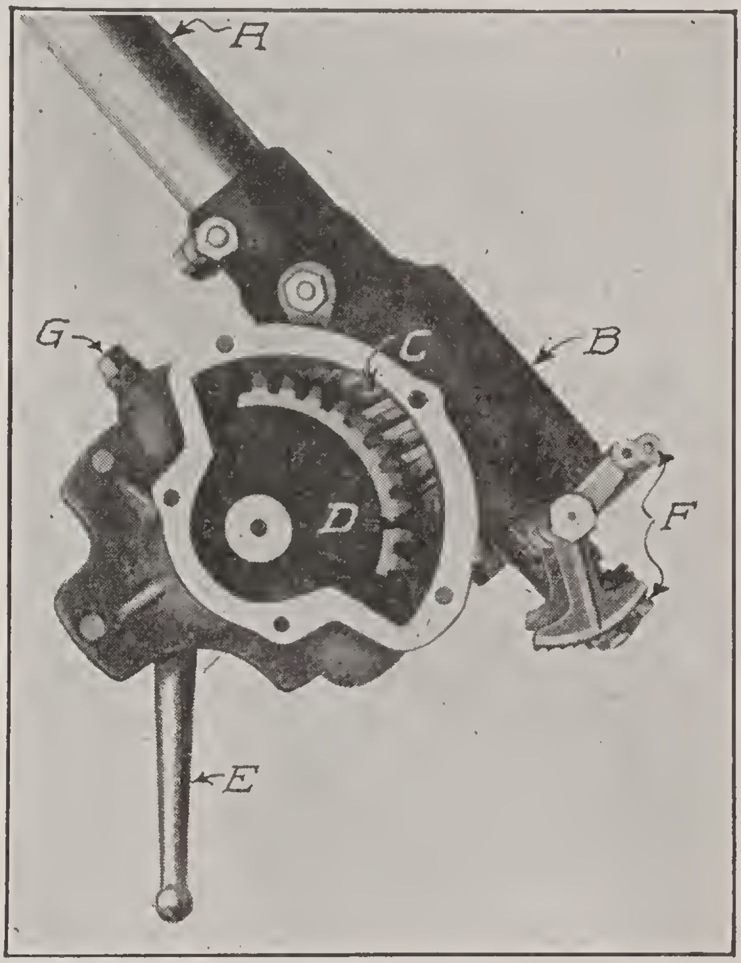


Fig. 322. Worm and Partial Gear Type of Steering Gear

Worm and Partial Gear. Fig. 322 illustrates a gear of the worm and partial gear type. Advantages claimed for the design are durability, ease of action, and adjustability to wear. The parts are accurately cut and hardened, and the worm is provided with a ball thrust on either side. With this type, the teeth, which are in the middle of the sector and in mesh, perform the greatest work when the car is driven in a straight line and are most susceptible to wear. To compensate for this wear, the center teeth are cut on a slightly less pitch radius so that lost motion may be eliminated without affecting the upper and lower teeth of the sector and to prevent binding when turning at right angles. In the illustration, *A* is the steering column to which the worm *C* is secured, *D* is the sector in mesh with the worm, *E* is the ball arm, or lever, *B* the gear housing, *F* the spark and throttle bevel gears and levers, and *G* the lubricant plug.

Adjustment. Two principal adjustments are provided. End play of the worm is eliminated by loosening the jamb nuts and lock screws on the column housing. Displacing the oil plug *G* will disclose an adjusting collar which is set with a screwdriver. Adjust collar until all play is eliminated, but the worm must turn easily. The lock screws, above referred to, are so located in the gear housing that when one is directly over a slot in the adjusting collar the other is between two slots. Consequently, after adjusting the collar it is essential that the proper screw be selected for locking the adjustment. Both locking members must be prevented from turning, by using the nuts. Wear of the teeth of the worm and sector may be eliminated by means of an eccentric bushing, which, when turned, moves the sector into a closer relation with the worm. This is accomplished by removing a locking screw at the left of the ball arm and moving the arm, which turns the eccentric bushing. In case of extreme wear, it may be necessary to displace the ball arm and set the locking-screw section in a different position on the end of the hexagonal end of the eccentric bushing so as to bring the arm in such a position that it can be locked by the screw. End play of the sector shaft is eliminated by removing a locking arm and turning an adjusting screw in, after which the arm and lock screw are replaced and both set up tight.

Worm and Full Gear. A full gear and worm type of steering gear is shown in Fig. 323, with the gear cover removed. This type is irreversible, and the advantage claimed for it is that it can be easily removed and so readjusted that an unworn section of the gear may be brought into contact with the worm. This is a simple form, and it is possible to replace a worn gear with a new one, as the gears are not expensive.

Fig. 324 shows a much more complicated form of worm and full gear in which the inventor has attempted to gain something by the use of a double steering gear, that is, two complete sets of worms and gears set opposing one another, the gears being made to mesh with each other just like a pair of spur gears. Since the lever can be attached to but one of the turning gears, the other gear with its actuating worm is useless. The inventor doubtless intended the two worms to oppose each other and thus be self-sustaining as to thrust, but such would not be the case, the actual thrust being in opposite directions in the two cases of the upper and lower worms, the total thus being double the usual amount.

Adjustment. The part most subject to wear is that section of the gear which meshes with the worm when the front wheels are traveling in approximately a straight line. Because of this wear, the teeth of the wheel are subject to deterioration. Usually the adjustment for the wear is made by bringing the worm into a closer relationship with the gear by using the eccentric bushings which support the worm shaft. This adjustment is practical when the lost motion is due to poor adjustment rather than to wear of the teeth. With the majority of types, it is possible to displace the steering arms, move the steering wheel about half a turn, then replace the worm wheel so that an unworn section opposite the worn teeth will be brought into engagement with a comparatively unworn portion of the worm proper. The eccentric bushings in this case can be utilized to obtain a correct meshing of the worm and gear teeth. End play of the worm

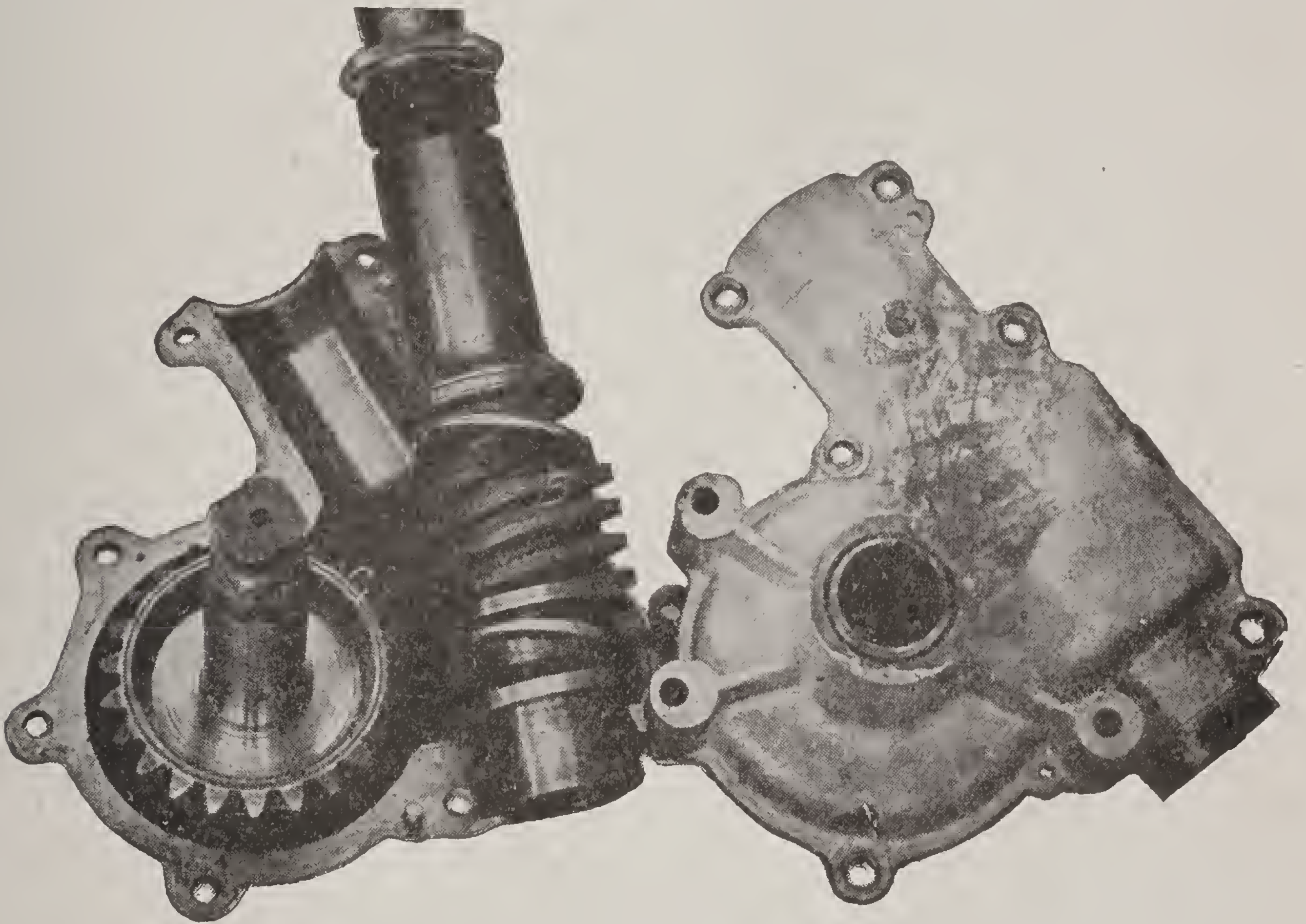


Fig. 323. Typical Worm and Full Gear Steering Device

can be removed by adjusting the ball thrust bearings on either side of the worm. Sometimes these bearings become dry, or the lubricant becomes gummy, causing the shaft to turn hard. Wear of plain bushings in the steering-gear case is responsible for lost motion; the remedy is to replace the bushings with new members.

Worm and Nut. Next to the worm and gear, either full or partial, the form of steering gear most used is the worm and nut, which is made in several different combinations. Thus, the nut may operate the steering lever directly through the medium of a secondary lever, or it may actuate a block, which, in turn, moves either the lever direct or the secondary lever. In Fig. 325 another form of the worm and nut variety is shown. This has a nut which the turning of the worm moves up and down but which is split, the two halves being bolted together. A spherical seat is formed in the two halves of the split nut into which a ball-end lever is set, the bolt serving to clamp the two pieces together and hold the lever there.

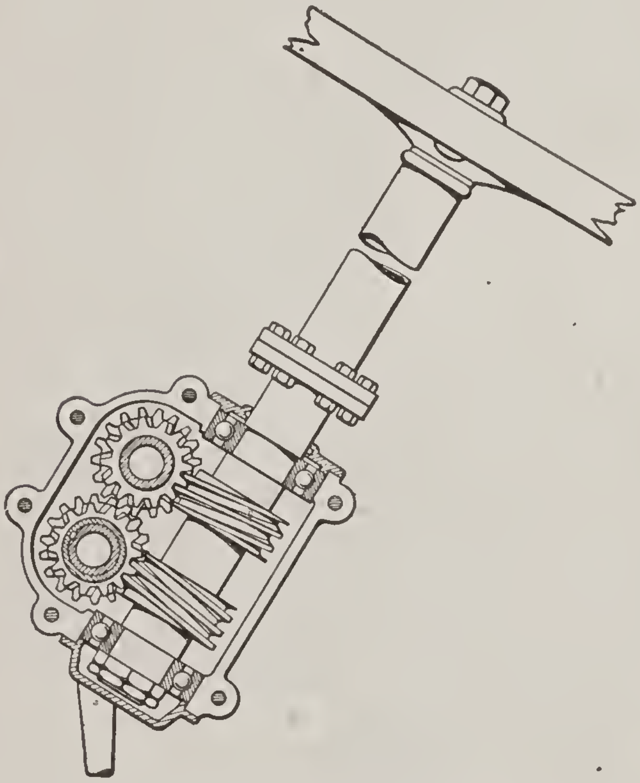


Fig. 324. Double Worm and Gear Steering Device

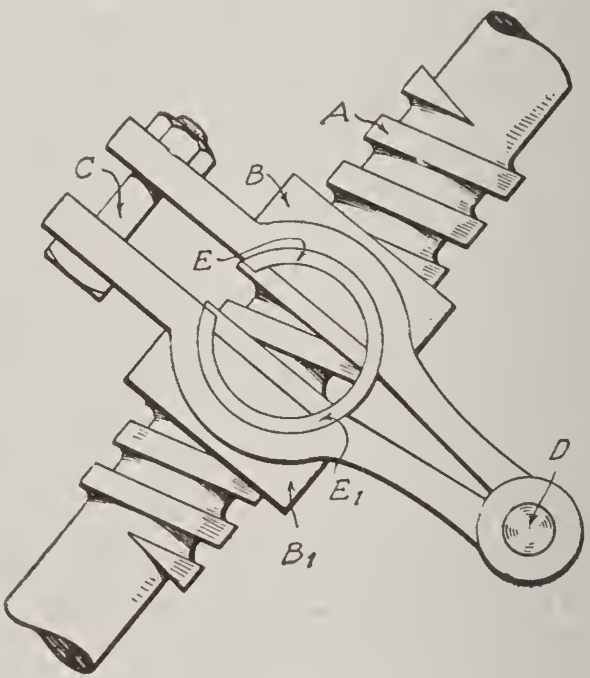


Fig. 325. Worm and Nut Steering Device

This is the end of the secondary lever, which is connected by means of another lever to the steering lever itself. In the figure, A is the worm, B and B_1 the two parts of the nut, C the clamping bolt, and D the hinge at the other end. E and E_1 represent the spherical seats for the ball end of the other lever.

Having the nut in two widely separated parts reduces the wear on each, since the bearing surface is spread out more than would be the case with an uncut nut. In addition, the split nut allows the changing of the ball-end lever at any and all times.

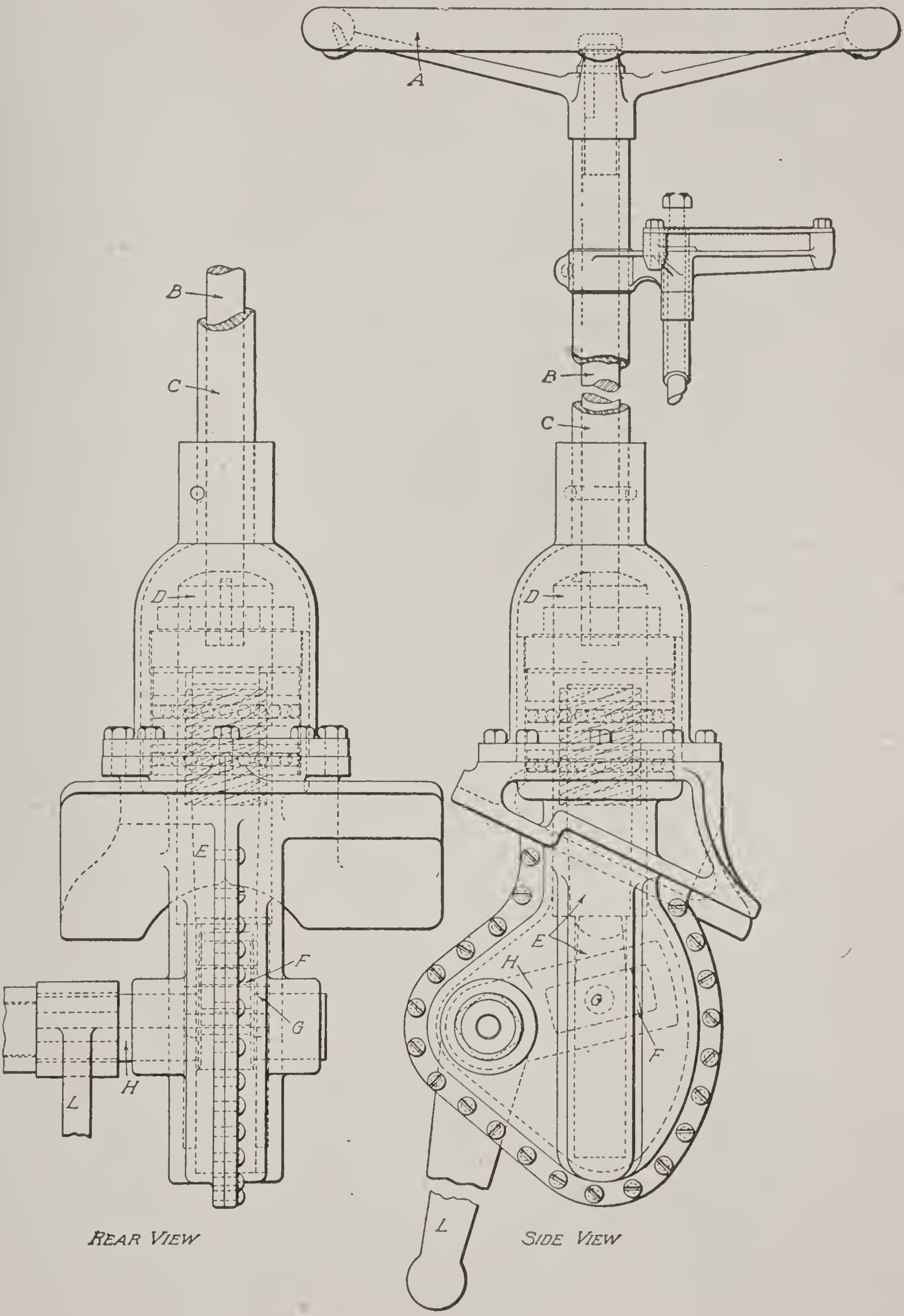


Fig. 326. Steering Gear Used on Heavy Manhattan Trucks

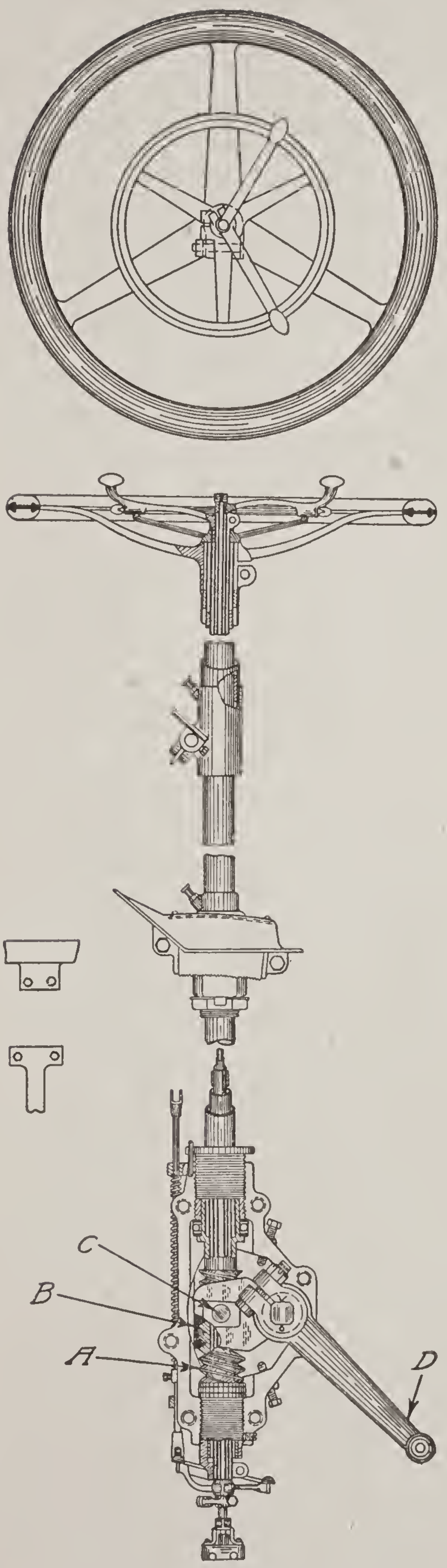


Fig. 327. Sectional Details of Steering Gear of Winton Cars
Winton Motor Car Company, Cleveland, Ohio

In Fig. 326 is shown a form of worm and nut steering gear which is used on very heavy trucks and commerical cars. In this gear, the double worm is used; the inner worm carries, at its lower end, a block which is pivoted in a combination lever and shaft, to which the steering arm is attached. In the figure, *A* is the hand wheel turning the rod *B* within the steering-post tube *C*. This rod is driven into and keyed at its lower end to a member *D* which has internal worm threads. Another member *E* has a circular upper end on which are worm threads, while its lower end is slotted. The worm at the upper end meshes with the internal worm threads in piece *D*, while the lower slotted end carries, between the two arms of the slot, a rectangular block *F*. This block is hardened and ground all over and is fastened to the forked end of piece *E* by means of the hardened and ground pin *G*. This pin also passes through the arm *H* of the shaft to which the steering arm is attached. The steering arm is free to rotate about the center. This rotation moves the steering lever *L* in the arm of a circle.

The steering action is as follows: Turning the hand wheel turns the outer worm. This worm cannot move, so the inner worm is forced to move up or down, as the case may be, and moves the block with the pin through it, which, being fixed in the arm extension of the shaft, must turn the shaft. To this arm is attached the steering lever, so the latter must move. Although a rather complicated gear to explain and also to make, this gear, when finished, is an excellent one, and has been used for five or six years on heavy trucks with excellent results.

The Winton steering gear, Fig. 327, is not decidedly different from the one just shown, as will be noted by a close inspection of the parts. *A* is the internal worm, which is turned by the hand wheel, while engaging this worm are the block *B* and pin *C*, the block being partly cut away to show the engaging gear teeth. This block moves the jaw arm of the steering lever *D*. This jaw is not complete in this gear, but is cut away to save weight. The jaw arm, too, is connected directly with the steering lever, the jaw, arm, and shaft making one piece. The light work to which this was put made possible the economy in the number of pieces and in the weight of each. As before, turning the hand wheel turns the worm, which, in turn, moves the block and pin up and down and thus moves the jaw arm, which moves the steering lever.

Adjustment. The adjustment for lost motion in the worm and split-nut type of gear is generally made by loosening a cap screw on the column and screwing down an adjusting nut which has a right-hand thread. This adjusting nut acts directly on the thrust bearing, forcing the screw and half nuts, which slide, against the yoke rollers. In making the adjustment to a gear of this type, it is advisable to turn the road wheels to the extreme angle position, because the gear is the least worn at this point, and if it is adjusted only enough to take up the play when in this position, there will be danger of binding. Sometimes, when the adjustment is made with the road wheels straight, the gear will bind at the extreme positions.

Worm and Worm. In the worm and worm form of steering gear there is a worm within a worm, not wholly unlike the ones just described. Fig. 328 shows an example of this, which has a worm *C* attached to the steering rod *H*, which is turned by the steering wheel *A*. Within and without this are worm threads, an external worm *B* meshing with the internal worm on the inside of *C*, while an internal worm *D* meshes with the external worm on *C*. The action of turning the hand wheel, then, moves one of these upward and the other downward.

The lower end B_1 of the inner worm member presses against a hardened end of the steering-lever arm E, while the lower end D_1 of the outer worm member presses against the other hardened end E_1 of the same piece. There is no lost motion, or play, in the gear; when the hand wheel is turned, one worm rises and the other falls, as just described; the piece E will let one end rise and the other fall, as it is acted upon by the lower extremities of the two moving worms. This piece is pivoted at F and carries at its outer end the steering lever G, which thus moves in the customary manner. Within the steering post are the spark and throttle tube and rod I and J, which carry right through the whole gear and out at the bottom, where the spark and throttle-actuating levers are attached.

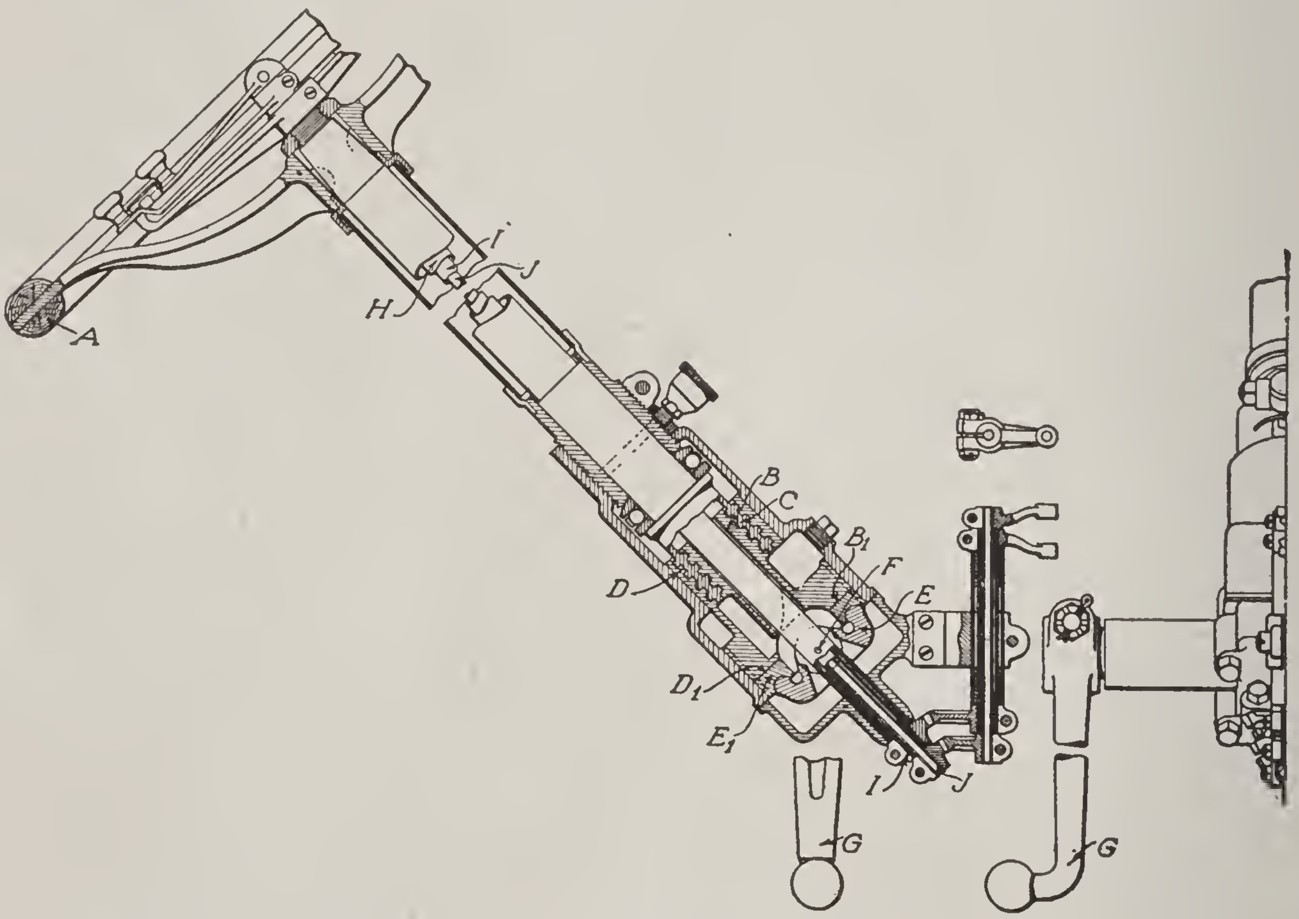


Fig. 328. Section of Gemmer Steering Gear
Courtesy of Gemmer Gear Company, Detroit, Michigan

Adjustment. The adjustment of the worm and worm type, an example of which is illustrated in Fig. 328, is generally effected by a nut located at the upper end of the gear housing. This nut is provided with flats to accommodate a wrench hold. The end of the worm-wheel shaft is squared, and to this square the steering-lever arms are attached by means of a pinch clamp and bolt.

Bevel Pinion and Sector. Among the other types of steering gears is that of the bevel pinion and sector, shown in Fig. 329. The bevel pinion moves the bevel-gear sector back and forth as it is turned, this motion being transferred to the steering arm attached on the same shaft to which the bevel sector is secured. This type of gear is said to be effective, but it is not irreversible, and shocks to the road wheels may be imparted to the steering wheel and move it.

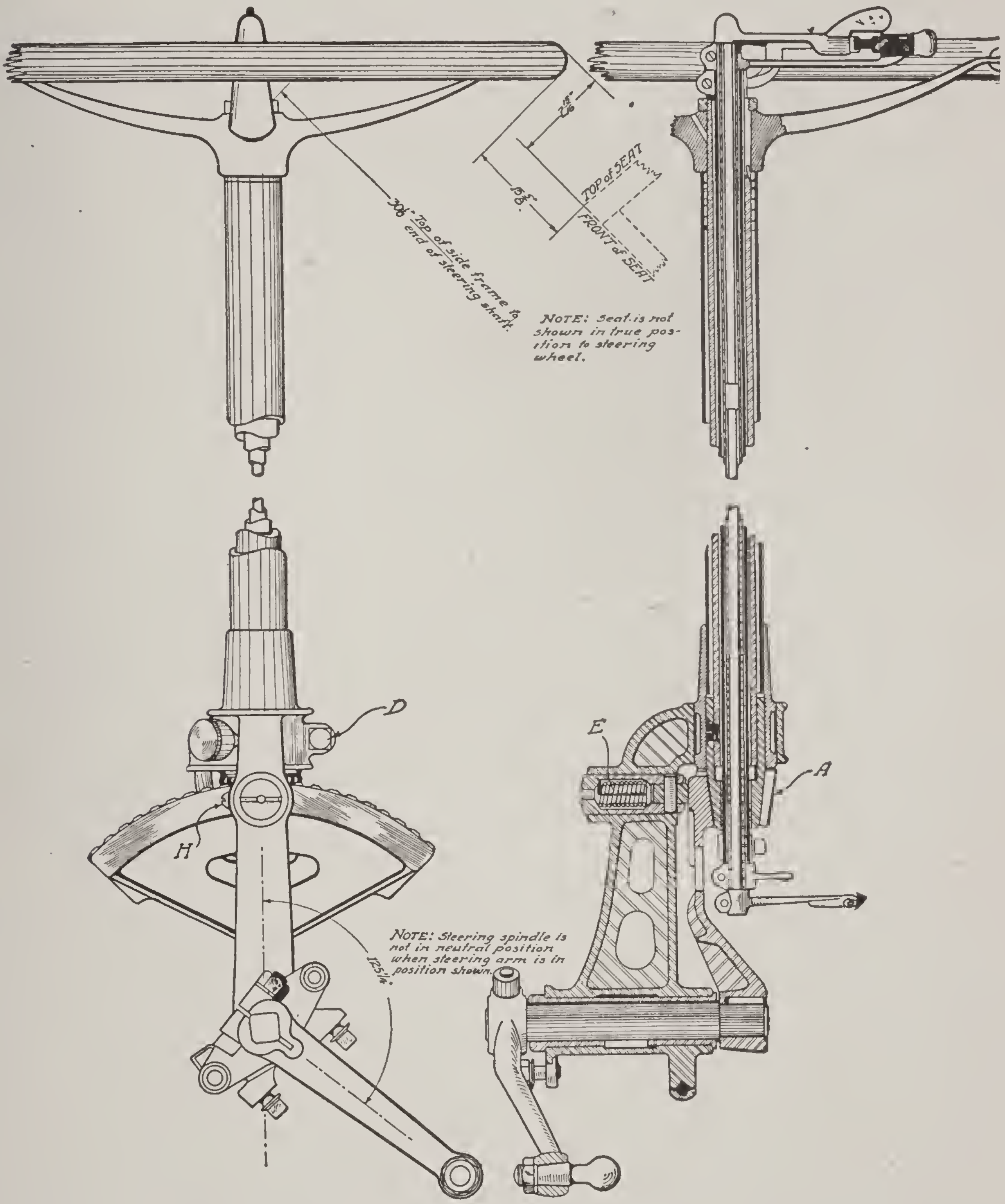

$2\frac{15}{16}''$
TOP of SEAT
$15\frac{5}{8}''$
FRONT of SEAT
$30\frac{1}{16}''$ Top of side frame to end of steering shaft.
NOTE: Seat is not shown in true position to steering wheel.
D
E
A
H
$125\frac{1}{4}''$
NOTE: Steering spindle is not in neutral position when steering arm is in position shown.

Fig. 329. Bevel Pinion and Sector Type of Steering Gear
Courtesy of Reo Motor Car Company, Lansing, Michigan

Adjustment. The bevel and sector gear has two adjustments. The pinion may be moved up or down, as required, by unlocking the clamp bolts (one of which is shown at *D*) which permits the moving of the entire steering column up or down so as to obtain the proper relative position to the pinion and its sector. The position of the sector endwise may be adjusted by the block member *A*, which bears against a roller guide, forcing the sector into mesh more or less closely with the pinion. The spring *E* is provided to prevent rattling, and the screw *H* is a guide for the plunger and should not be disturbed in making the adjustment.

Hindley Worm Gear. There are a number of things about the Hindley type of worm which make it an excellent one to use for steering gears. A realization of this advantage is bringing about a greatly increased use of this form; so it will be appropriate and timely to look into its form, construction, and advantages.

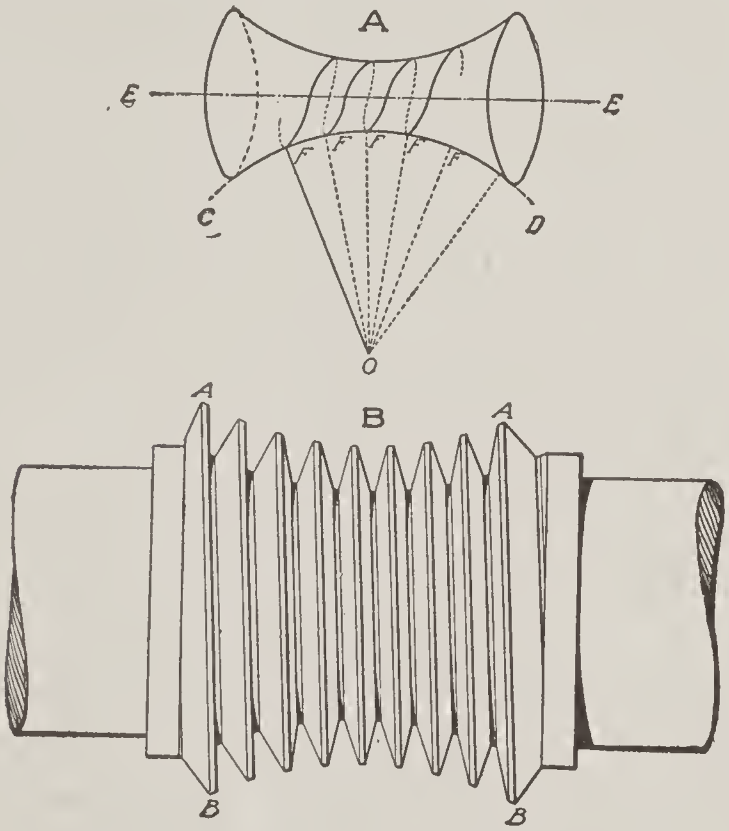


Fig. 330. Details of the Hindley Worm

The question of what makes the Hindley different from other worms naturally arises. The ordinary worm has the same diameter from one end to the other, the blank before the cutting of the teeth resembling a section of a cylinder. The Hindley, on the other hand, is not of uniform diameter, but has a smaller center diameter and enlarged ends. This gives it a waist, or hour-glass, shape.

An illustration will make this clear. Fig. 330 shows at *A* how the Hindley shape is generated and at *B* a finished gear, revealing plainly the reduced center diameter. In the upper figure, *EE* is the center line, or axis, of the worm, and *O* the center of the gear which is to mesh with it. *CD* is a circular arc struck from *O* as a center. If, on this curve *CD*, equal spaces be struck off, using a distance equal to the pitch of a single-threaded worm or the lead of a multiple-threaded one, as at *F*, and radial lines be drawn from the center *O* to these points, these lines will be normal to the surface of the worm at those points; in short, the worm must pass through them, as roughly sketched in the figure. In the lower part *B*, of the figure, is illustrated a worm made on this principle, ready to be put into position.

This form of worm is used for the double reason of presenting more wearing surface—since it has at least three teeth in contact at any one time, as compared with one or at most two in the ordinary worm—and greater resistance to reversibility. The worm is used for steering gears because it is partly or wholly irreversible, its motion being a sliding one; nevertheless, all worms may be so cut as to be either wholly or not at all reversible. The sliding motion of the two parts in contact, as opposed to the rolling motion in the case of other mechanical movements of a similar nature, is greatly increased if there are three teeth in contact instead of the more usual one. If the friction of sliding be increased, the amount of reversibility will be decreased in the same proportion, for the added sliding friction will increase the natural reluctance of the worm to transmit power backwards. So much is this the case that it pays to use the Hindley form, despite its greatly increased cost of cutting.

Ford Steering Gear. The steering mechanism of the Ford car—a patented construction—differs radically from the conventional types in that its hand wheel does not directly rotate, or turn, the steering column or rod, but it imparts the necessary turning movement through the gearing and the use of a small shaft to which the hand wheel is attached. A phantom view of the gearing is shown in Fig. 331.

The steering column with its short shaft and drive pinion is enclosed in a tube or housing which is set at an angle and bolted to the dash. The housing does not extend the entire length of the column, as the lower end of it is mounted in a bracket that is rigidly bolted to the frame. The steering-gear post, or column, has a triangular flange at right angles to the rod, and each point of the flange has an integral stub, or pin, carrying a small spur pinion. The center of the rod is drilled and bushed to take a small shaft to which a fourth pinion, or drive pinion, is keyed. The upper part of the housing is shaped so as to provide a gear case, and the inner periphery of this case is cut to obtain spur teeth or, in other words, an internal ring gear. This gear is stationary.

The hand wheel is attached to the short shaft, and its drive pinion is held in place by a brass cover of the internal gear case. As the drive pinion of the shaft is in mesh with the three pinions mounted on the stubs of the steering column proper, and these three pinions are in mesh with the internal ring gear, any movement of the hand wheel will rotate the drive pinion on its shaft. This movement will cause the three spur pinions to rotate in an opposite direction against the internal gear, thus reducing the movement of the steering column as compared to that of the hand wheel. The three spur pinions compensate for any pressure of the drag link and the tie rod.

The operation of the Ford steering-gear mechanism explains the basic principle of the operation of the hand wheel; that is why the wheel is turned in the same direction that the driver desires the car to go. If the hand wheel is revolved from left to right, for example, the movement causes the three pinions mounted on the pins of the steering column to rotate from right to left; the pinions rotating against the stationary internal gear turn the steering rod in the same direction taken by the three pinions. The column swings an arm attached to it from right to left, and, as the rod is secured to this arm, it moves in the same direction, swinging the front road wheels so that they move from left to right, and to a degree that will correspond with the turning, or movement, of the hand wheel. It should be understood that the movement from left to right refers to the front half of the road wheels. If the driver desires to direct the vehicle to the left, the wheel is turned to the left.

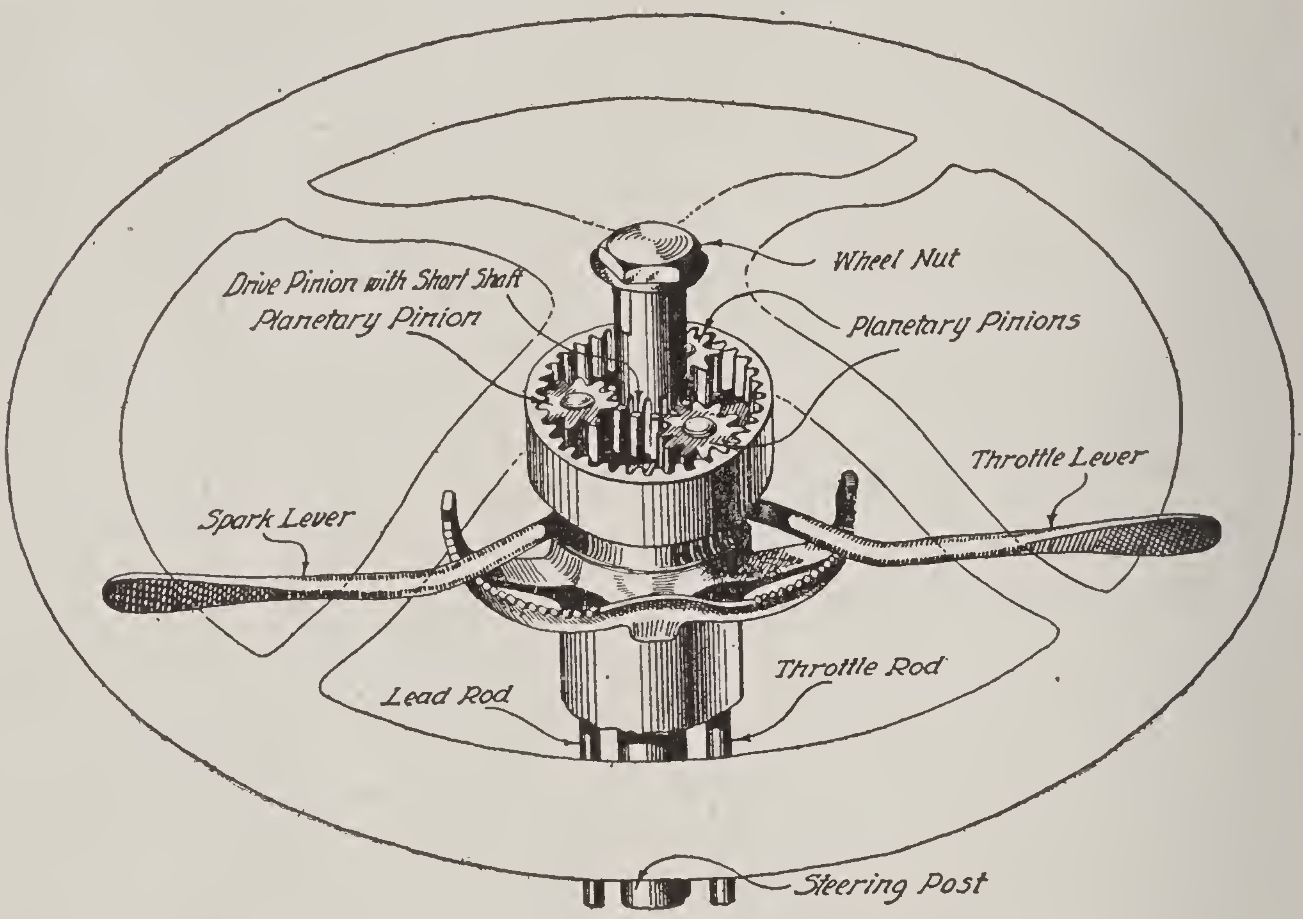


Fig. 331. Ford Planetary Steering Gear—An Unconventional Type

The drag link of the Ford steering gear differs from conventional designs in that it is at right angles to the frame and is practically two-thirds the length of the tie rod. The end of the steering column is provided with an arm carrying a ball, and the drag link, or steering-gear connecting rod, as it is listed by Ford, has a ball-socket cap which fits over the ball of the steering rod. The drag link also has a ball socket at its other end, which fits over a ball arm on the tie rod. The tie rod, called the spindle connecting rod because it connects the spindles, is provided with yokes at either end, and these yokes are pivotally connected to the spindles by a bolt passing through them and through an eye in the spindle. The Ford drag link differs from others in usual practice in that it moves to the right and left, while those used on other cars move forward and backward. No provision is made with the Ford drag link for absorbing shocks or for automatically compensating for wear as usually is the case with the conventional type of drag link.

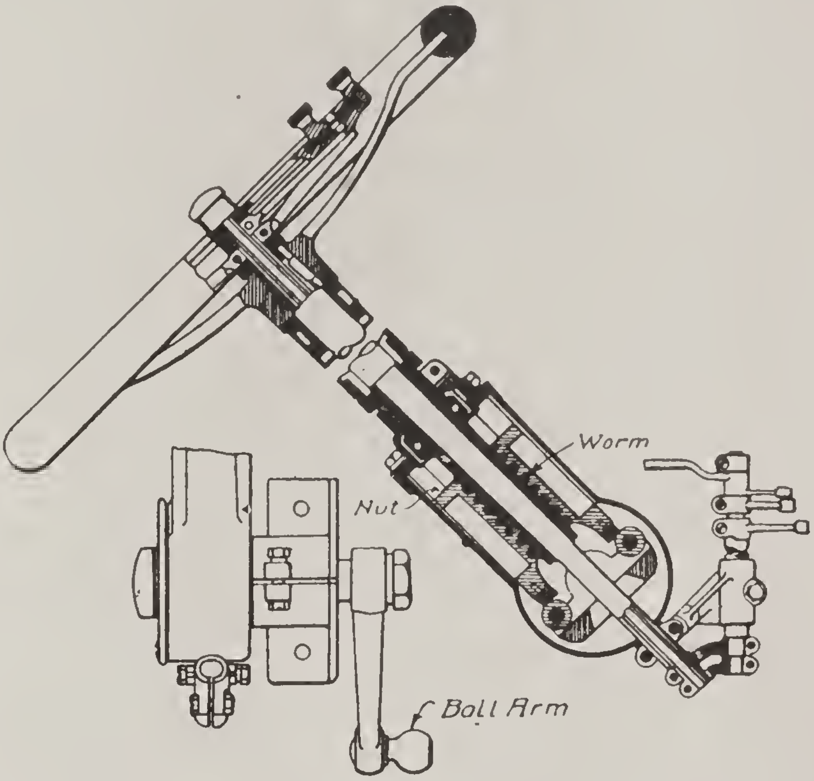


Fig. 332. Screw and Nut Gear Used on Trucks

Semi=Reversible Gear. The steering gear used on commercial cars, particularly trucks ranging from 3- to 7-ton capacity, must not only be capable of operation with a minimum effort, but it must absorb a great many of the minor shocks and a per cent of the larger shocks. The semi-irreversible type is most favored because of the above-named reasons. The design shown in Fig. 332 is of the screw and nut type. The nut is a solid piece, completely enveloping the screw, and the threads of the screw are in constant and complete engagement with the threads in the nut. The screw has a rotary motion and the nut has a longitudinal motion. The means of transmitting this longitudinal motion of the nut to the rotary motion of the steering arm is by circular discs at the lower end of the nut.

These discs present constant bearing surfaces to the recesses in the nut, and are provided with slots into which the projecting levers from the rocker shaft fit. The screw pulls the nut up or down in the housing, and there is no tendency for this nut to be moved sideways.

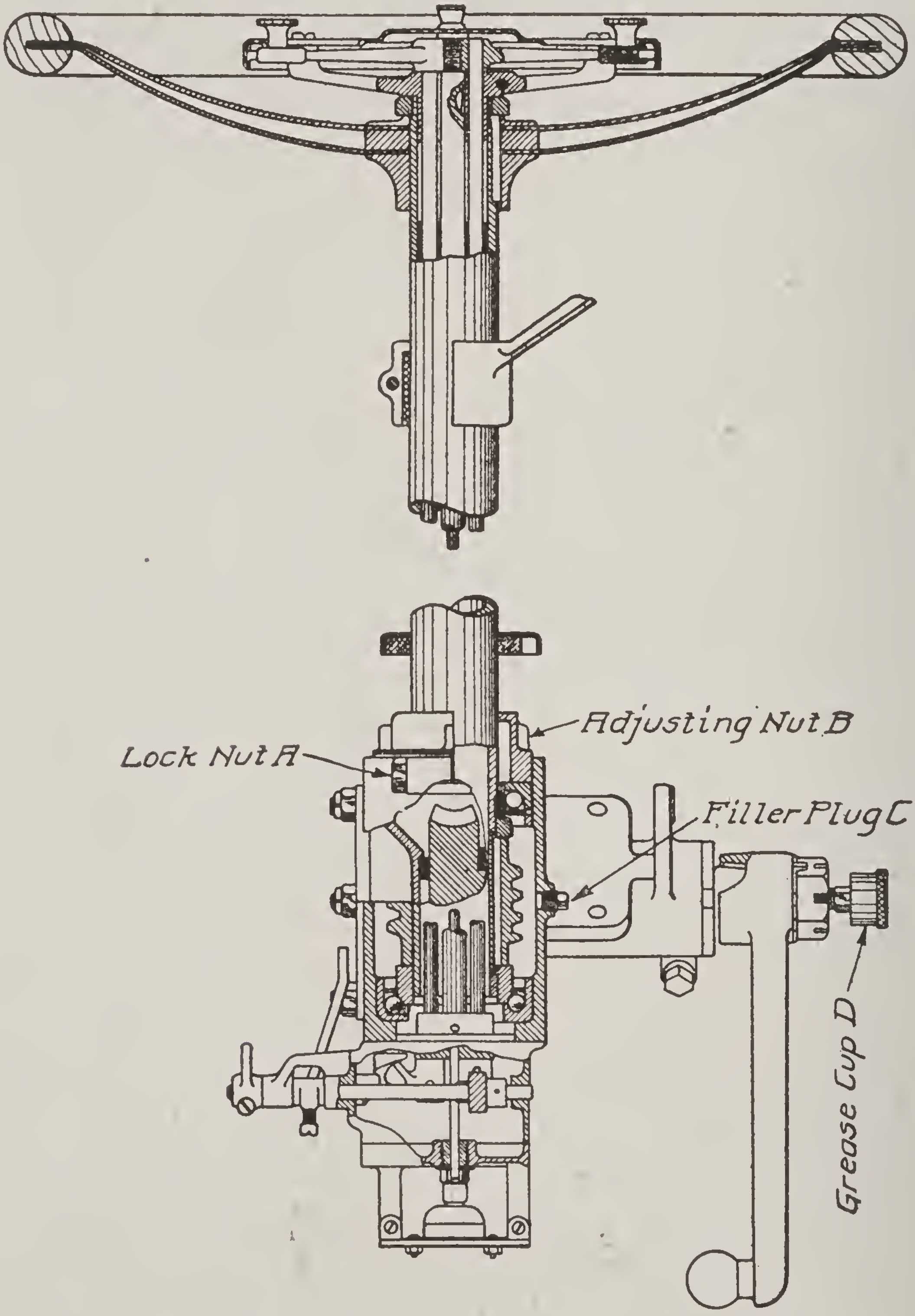


Fig. 333. Worm and Gear Steering Arrangement—Semi-Reversible

The levers projecting from the rocker shaft into the swivels which rotate in the lower part of the nut are in direct line with the screw, so that the push and pull of the nut is in a straight line.

Removing Steering Gear. To disassemble the majority of steering gears it is necessary to remove the unit. With the type shown in Fig. 333, which is a semi-irreversible worm and gear, the removal may be accomplished by displacing the control levers at the top of the column and dropping the unit down through the frame. The adjustment of this type for end play is made by loosening the locking nut *A* and turning down the nut *B* until the play is eliminated.

STEERING-GEAR ASSEMBLY TROUBLES AND REPAIRS

Lost Motion and Backlash. Lost motion of the steering wheel does not always indicate that the steering gear is at fault, for wear in the steering-gear assembly usually takes place first in the clevis pins, yokes, and connections of the drag link. The spindles, spindle bolts, and wheel bearings are factors. Despite the fact that the front road wheels are deflected but a few degrees the spindles, bolts, or bushings may be worn, as these parts are subject to radial and thrust loads. The spindle bolt, which does not move, tends to wear oval; adding to this tendency the wear of the spindle bushings, one has considerable lost motion to contend with. Wear of the wheel bearings contributes to the apparent lost motion of the steering gear as do the connections of the drag link. Taking all of these factors into consideration, and allowing but a small fraction of an inch for play of each worn part, the sum total may result in considerable movement of the hand wheel before the road wheels are deflected.

Lost Motion in Wheel. While there should be a certain amount of movement to the hand wheel before it actuates the road wheels, the lost motion, as a rule, does not exceed $\frac{1}{4}$ or $\frac{3}{8}$ inch when the gear is new. This amount is essential as without some free movement the steering of the vehicle would be tiresome. Wheels may be keyed or pinned to the column. When play exists as the result of a worn key, pin, or slots, the remedy is to re-cut the seats and make and fit a new key or pin. With some types of wheels the use of a wheel puller will be necessary to displace them. Another cause of lost motion, when the wheel is tight and linkage free from play, is a loose key retaining the worm or gears of the steering gear proper. A simple test of the hand wheel is to hold the tube, or post, securely and move the hand wheel. The amount of play in the drag link can be ascertained by grasping it about midway and trying to move it backward or forward or in the normal direction of travel. Hold the ball arm of the steering gear when making this test.

The amount of backlash present in the irreversible and semi-irreversible types of steering gears may be determined by disconnecting the drag link, grasping the ball arm, and moving it up and down and back and forth. Worn bushings in the steering-gear case are frequently the cause of movement of the column as a whole. Another component that should not be overlooked in the search for the cause of lost motion is the ball arm. Movement of this member on its shaft can usually be eliminated by tightening the nut.

STEERING WHEELS

Different Forms of Hand Wheels. *Wood Rim.* A variety of material is utilized in the construction of the wheel, which has superseded the lever or tiller. The section or sections of the wheel or rim are circular, oval, or elliptical; the oval, or ellipse, is turned upward. The strength of the wheel varies according to the material used and the process of assembly. The all wood wheel has not the strength of a built-up wheel with a metal core, but it is simpler and cheaper to manufacture. With the exception of the molded rubber type of rim, the majority of the wheels, particularly those fitted to high-grade cars, are built-up. Mahogany, circassian walnut, and black walnut are the materials favored. The wood is cut to short sectors of an annular ring of about 2 inches in width and so glued together as to eliminate joints.

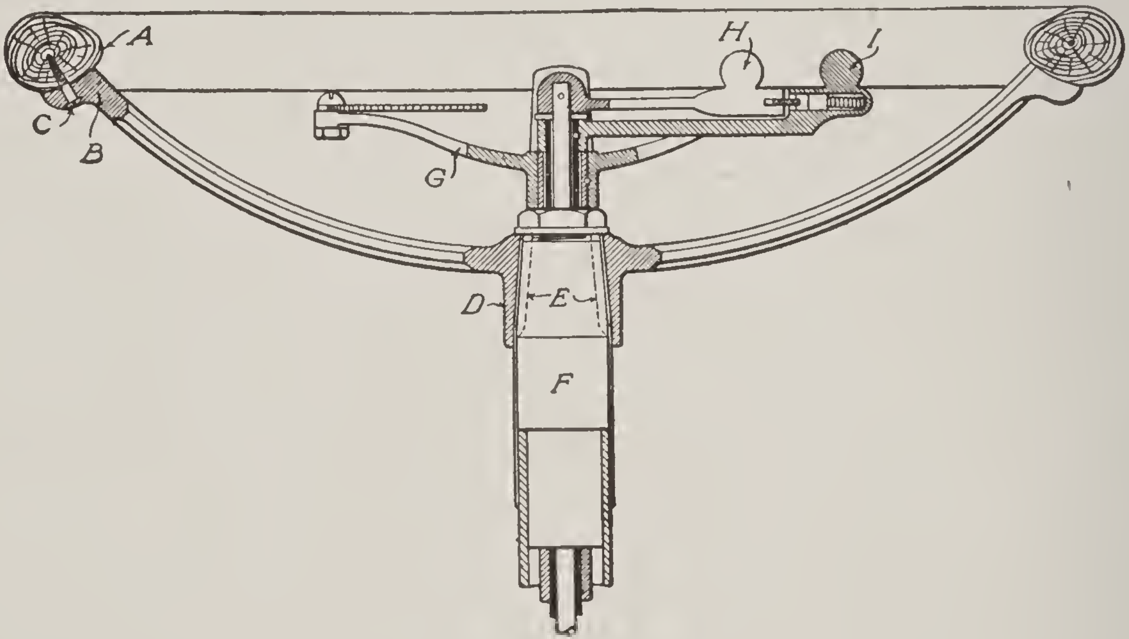


Fig. 334. Section through Typical Steering Wheel

The method of attaching the rim to the spokes of the wheel spider is by screws, and this method is illustrated in Fig. 334. *A* indicates the wood member, *B* the arms, or spokes, which have a boss through which the screw *C* passes into the wood. The hub of the spider *D* is attached to the steering post by two keys *E*.

Metal Core with Wood Covering. When the wheel design is made up of a metal core the ring is cast on the spider or integral with it. Coverings of wood concealing the ring are used, although with some types, a section of the ring may be noted. This type of wheel possesses great strength and the wood veneers can be secured at more frequent intervals than in the design previously described.

Different Wheels for Commercial Use. *Truck Types.* For the light delivery wagon, taxicab, and similar cars, no difference in the steering wheel is made, but when it comes to the heavier service, there is a need for a heavier wheel. This does not mean a heavier rim only, but a heavier, more rugged gear all the way through. The weight on the front wheels of a heavy truck is very great, and the tires, which are of solid rubber, may have frictional contact with the pavement of several inches in width. All this combines to make turning the vehicle from the driver's seat more difficult.

For this reason the driver must have a greater leverage, which means a larger diameter of the wheel. Then, too, the rim should be bigger in section in order to withstand the harder use of commercial service, and to provide for the large hands of the operators. Greater strain upon the rim of the wheel, on attempting to turn heavier weights with it, means that the rim must be fastened to the spider more securely. This means more arms, the four generally used for pleasure cars being increased to five for trucks. While this helps a great deal, since it provides five screws instead of four, it is not sufficient, and most of the big trucks today are equipped with steering wheels in which the rim is built over a central metal rim of the spider.

Pleasure-Car Types. Usual pleasure-car practice varies from 14-inch up to 16-inch wheels, while commercial car sizes begin at 16-inch and run up to 18-inch wheels on light trucks, and as high as 20- and 22-inch wheels on heavy trucks. Rim sizes vary considerably, a favorite for touring cars being an oval with from $\frac{3}{4}$- to $\frac{7}{8}$-inch vertical height and a length of about $1\frac{1}{16}$ to $1\frac{3}{16}$ inches. These figures have no connection with commercial work, the smallest being 1 inch and on up to $1\frac{1}{8}$ inches in height, with the long diameters varying from $1\frac{1}{4}$ up to $1\frac{3}{4}$ inches. For speed work, racing, and the like, it is usual practice for the operator to wind the surface of the wheel with string, this giving a rough surface upon which the hands will not slip. This is practiced, too, by many truck drivers, who claim that the strains of steering the big vehicle are not felt as much when the wheel is thus wound.

To preserve the nice appearance of the steering wheel and still give the roughened surface to which the hands will cling easily, even in wet weather, many manufacturers are making a wheel of molded rubber, the use of this material allowing the formation of the wheel in any desired section, as is seen in Fig. 335. As a concession to appearances, these wheels are usually made with a plain upper surface; the lower or under surface, however, being made in a series of depres-

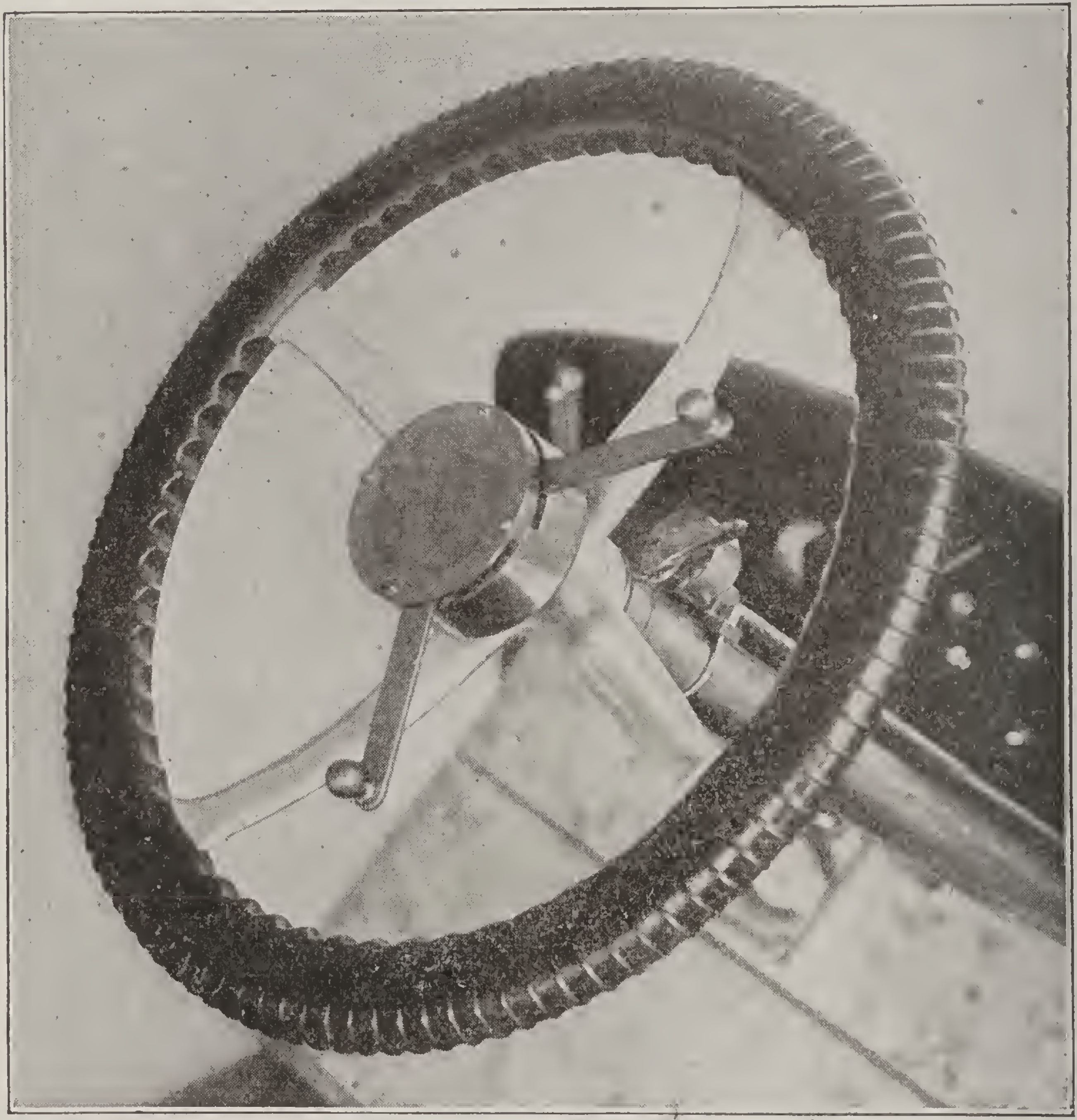


Fig. 335. Molded Rubber Steering Rim on S.G.V. Car
Courtesy of S.G.V. Company, Newark, New Jersey

sions and humps, between which the fingers find a good resting place. This gives a good grip, as the under side of the wheel seldom gets wet.

Folding Steering Wheels. Although tilting steering wheels were introduced several years ago, they did not meet with favor until the Cadillac adopted them as standard equipment. The wheel, which is 18 inches in diameter and has an aluminum spider, is hinged to drop downward, a design facilitating entrance and exit at either side of the car and making it possible to attain the driver's seat without squeezing. The Cadillac wheel is shown in Fig. 336, while that used on the King car, illustrated in Fig. 337, is of the tilting type. To operate the design, the wheel is turned until the wheel spider arm carrying the release button is convenient to the thumb of the right hand. The button is pushed to the right, and, by using both hands, the wheel is pushed forward and upward. The Herff type, shown in Fig. 338, is of the true hinged form; the rim is thrown up and out of the way, that is, the rim only, as the quadrant carrying the spark and

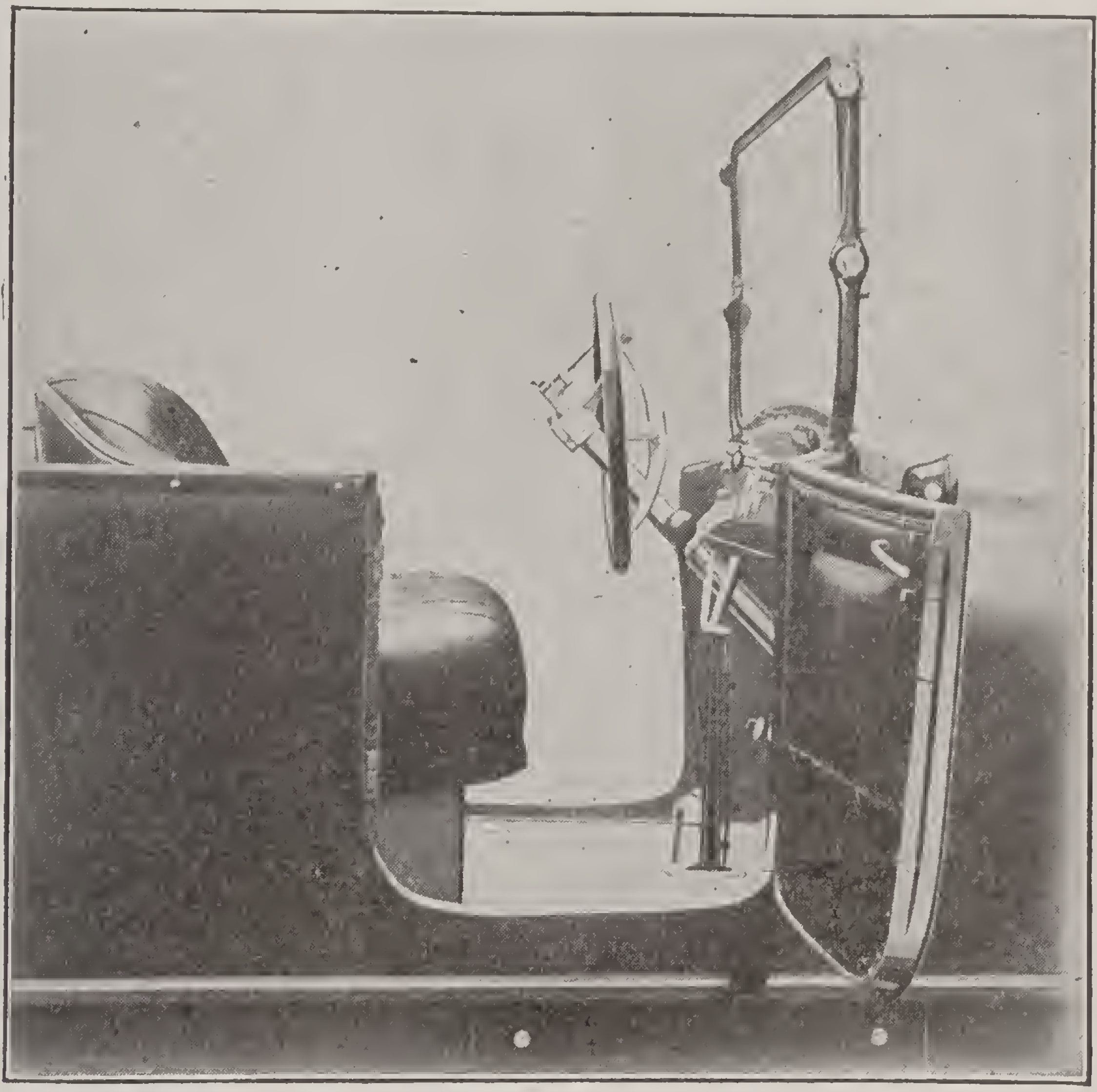


Fig. 336. Hinge Type of Steering Wheel Used on Cadillac

throttle levers remains. There are several other types marketed, but their working principles are similar.

Throttle and Spark Levers. In the usual case, the arms of the steering wheel have the quadrant for the spark and throttle levers fastened to them. The levers are operated within the space inside of the rim of wood and above the spider of metal; the latter is usually at a lower level by several inches, as shown in the figure. In Fig. 334, however, the quadrant is not carried by the spider arms, but on a separate framework *G*, or spider of its own, up above the hub of the wheel. Over this framework the spark and throttle levers *H* and *I* work, serrations of teeth in the quadrant preventing the levers from moving, except when they are sprung off by the pressure of the fingers operating them. In some cases, these teeth are done away with and friction surfaces are substituted; springs holding the contact surfaces together are so light as not to interfere with the moving of the levers by hand.

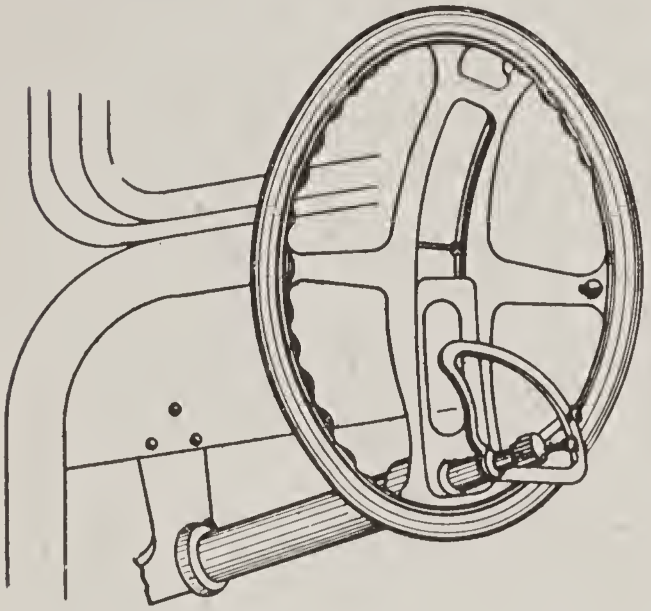


Fig. 337. Tilting Steering Wheel on the King Car

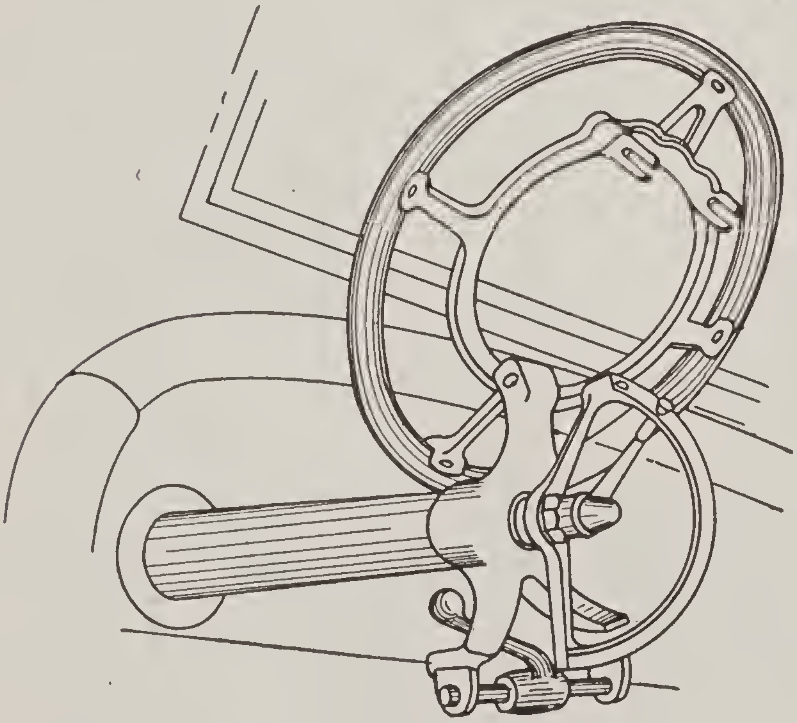


Fig. 338. Herff-Brooks Folding Steering Wheel

STEERING ROD, OR DRAG LINK

Operation. By the steering rod, or drag link, is meant the member connecting the ball arm, or lever, of the steering gear to the lever attached to the steering knuckle. This is clearly illustrated in Fig. 339. The steering gear is marked *D*, the steering arm projecting down from it *C*, while the steering rod which connects the lower end of the arm with the lever on the knuckle is marked *AB*. *F* is the knuckle pivoted in the axle, which carries the two-end lever *E*, one arm of which has the steering rod attached to it at *B*, while the other carries the cross-connecting rod joining the two knuckles together. Since the pivot point is fixed, any movement imparted to the knuckle must result in its swinging about the pivot point and carrying the wheels with it.

This movement is imparted by the steering rod to the end *B* of the arm *E*. The steering rod itself simply connects with the steering lever *C*, swinging back and forth in a vertical plane with the steering knuckle *F*, which swings around and back in a horizontal plane, and imparts the movement of the lever to the knuckle. Since the end of the steering lever rises and falls and the end of the lever on the knuckle maintains a constant level, although moving in a circle, the rod must have a universal joint at one end. This is really a necessity from two points of view: to allow the rear end to move up and down vertically while the front end swings around in a circle; and also to allow the front end to swing in a circle set in one horizontal plane, while the rear end remains stationary or practically so in that plane. In short, the two ends move continuously, each in its own plane, but the two planes never coincide—the one is always vertical, while the other always stays horizontal. This necessitates at least one universal joint. Many makers play on the safe side, and lower the cost of

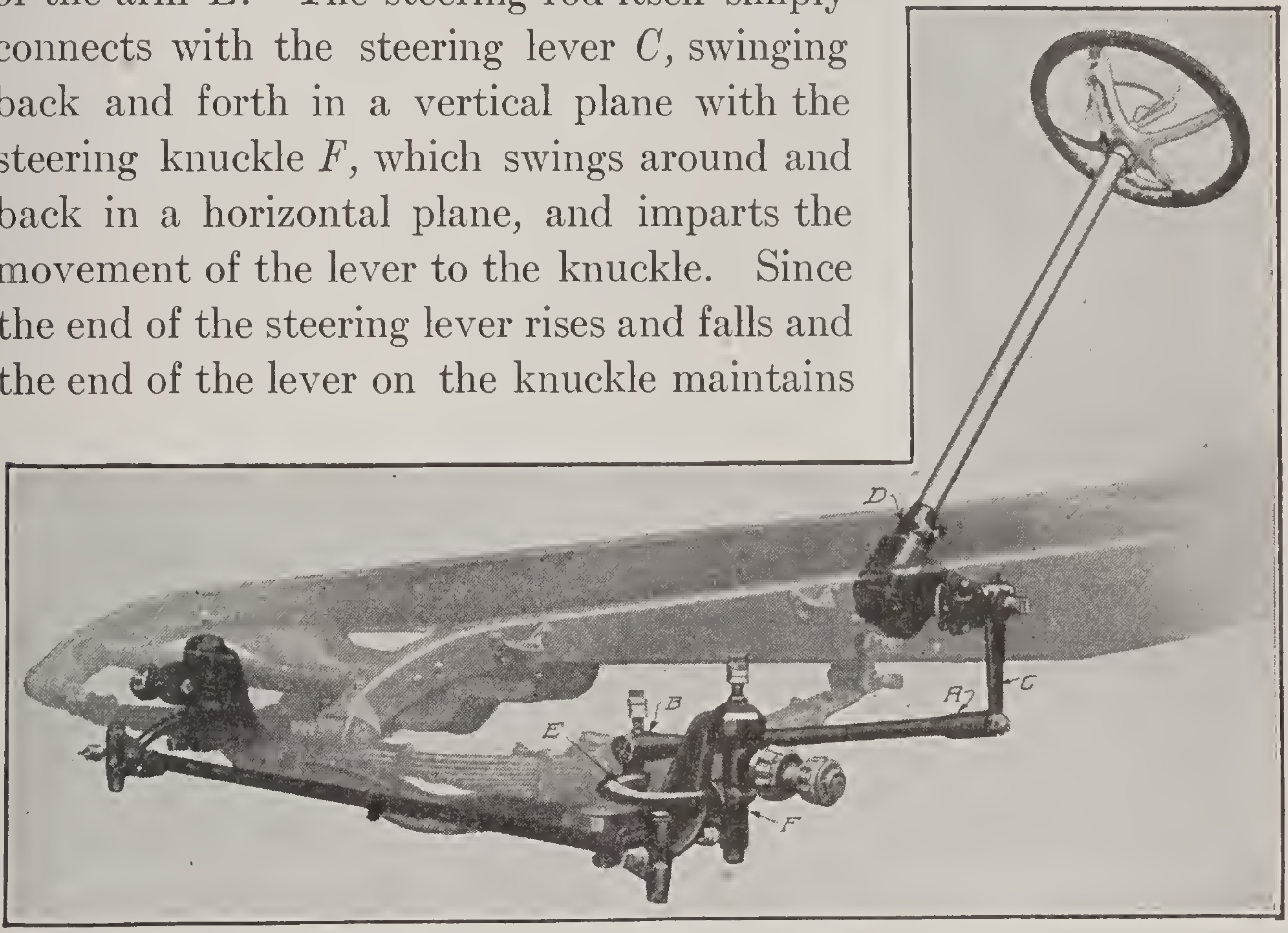


Fig. 339. Typical Steering Arrangement on Pleasure Car

production by making the two ends alike—a universal joint on each one.

Types of Construction. A glance at the construction shown in Fig. 340, and also in Fig. 341, shows a steering lever made with a ball end, or partial ball end, upon which the steering rod is hung. In this, the partial ball is formed in the center of a bar, the inner end of which is threaded and screwed into the steering arm, with a nut on the outside to prevent its backing out. The ball itself is made separately and slid on over the rounded end of the shaft, or axis. After this a sleeve is put on, followed by a nut which holds the sleeve up tight against the ball. The function of the sleeve is to give the spherical end of the rod plenty of play in a sidewise direction. This is a cheap form of construction, but could have been made in one piece had it been desirable or necessary to do so. Such a form has a metal-to-metal contact, which is hard upon both ball and socket, necessitating frequent and costly replacements. These replacements are obviated by backing the ball socket up with a spring or springs, as is shown in Fig. 341. This form of construction is now quite generally used; the socket of the ball in the inner end of the rod is set inside of a sleeve with a spring on each side of it. These springs not only take up the road shocks but the wear as well, the shoulder against which they rest being adjustable. In this figure, *J* is the lower end of the steering lever with the ball end. This lever is mounted in the ball socket *G*. *A* is the body of the steering rod, which is expanded at the end to a larger diameter, this being designated in the figure as *B*. Within this expanded portion, the sleeve *E* at one end acts as a shoulder for the spring *F*.

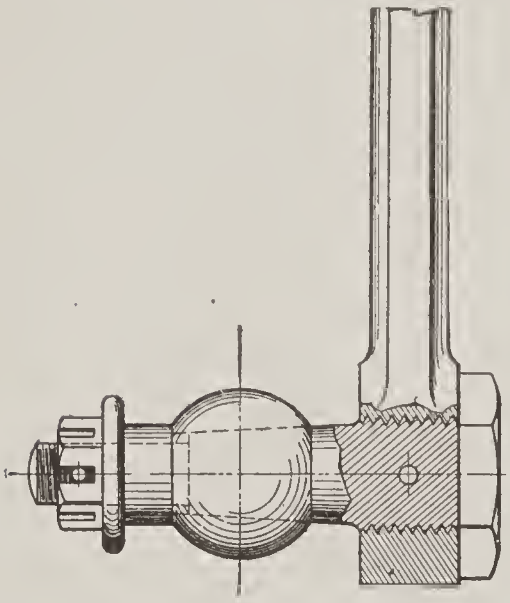


Fig. 340. Steering Lever with Ball End

At the other end, the outside of the sleeve is threaded to receive the collar *C* with the hexagon end *K*. Within this, a second spring *L* holds the socket up to its position. The location of the collar *C* determines the tension of the spring *L*, and this is locked in its position by the screw *V*. Should there be wear, which necessitates the moving of the ball toward the open, or left, end, the whole thing is disassembled and a longer sleeve inserted in place of the one shown at *E*. On the other hand, ordinary wear is compensated for by taking up on the collar *C*, first loosening the lock screw *V*.

In Fig. 342, a rod is shown assembled at the top and disassembled into its components at the bottom. The two ends differ, one being but a simple yoke with a plain bolt through it, marked *D*. The other, however, is a ball end with an adjustment and with springs to take up shocks.

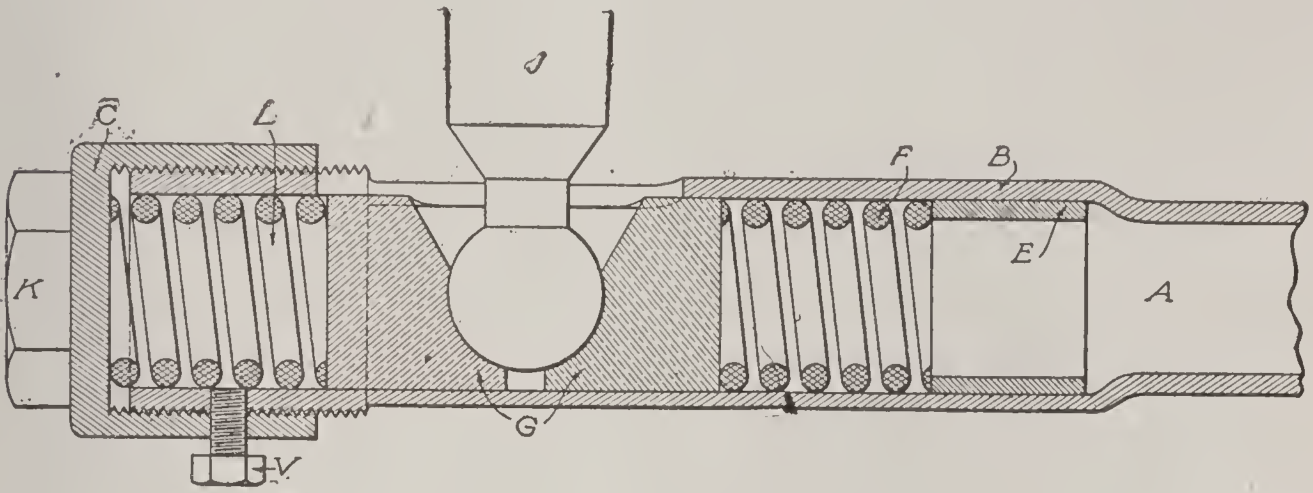


Fig. 341. Adjustable Form of Ball-End Steering Rod

All these parts are marked in the figure and may be located by letter. The body of the rod is marked *A*, the expanded end *B*, which has a groove *H* cut in it. Into the inner end of this groove is fitted, first, the spring *F;* second, the two halves of the ball socket *G;* and third, another spring. The sleeve *E* closes the outer end, and over the exterior is screwed the adjusting nut *C*. The nut and sleeve are held in place by the locking pin *V*, which passes through the outer nut, the shell end of the rod, and the inner spacing sleeve, the ends being riveted over to hold it in place. This form limits the adjust-

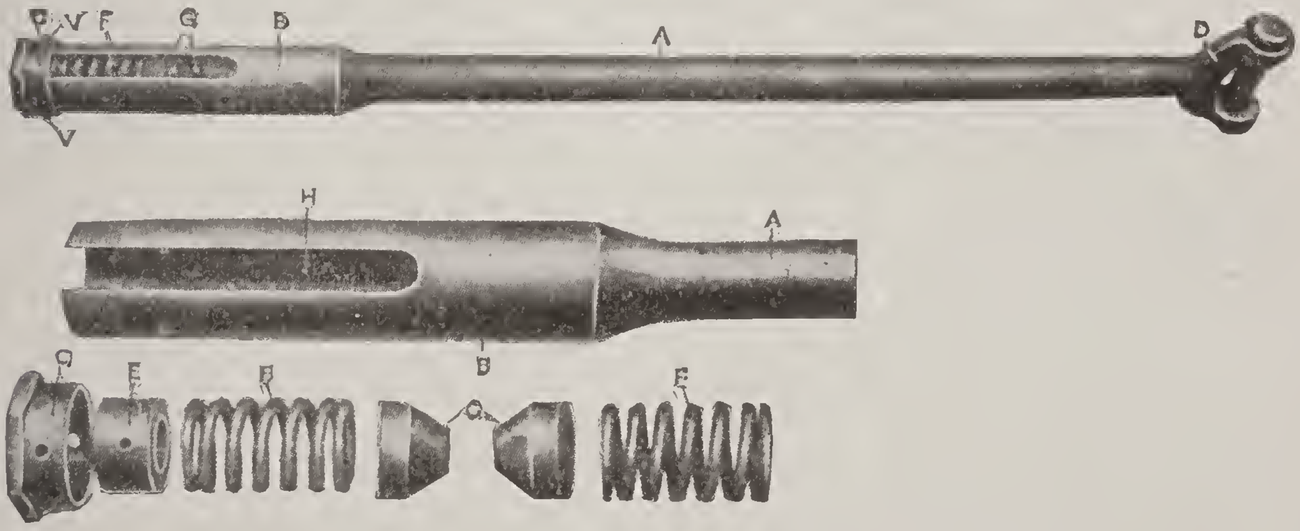


Fig. 342. Cross-Connecting Rod Assembled and in Parts

ment to a full half turn of the nut, while the pin would soon need replacement if much adjusting were done, as some of its length would be lost each time it was riveted over because of the chipping away to allow it to be taken out.

Cross=Connecting, or Tie, Rods. The object of the cross-connecting, or tie, rod is to connect the right- and left-hand steering knuckles so that the road wheels will be turned alike. The general practice is to place the rod back of the front axle, a location avoiding the possibility of damage if an obstruction in the road is encountered, but in some instances the tie rod is placed in front, as in Fig. 339.

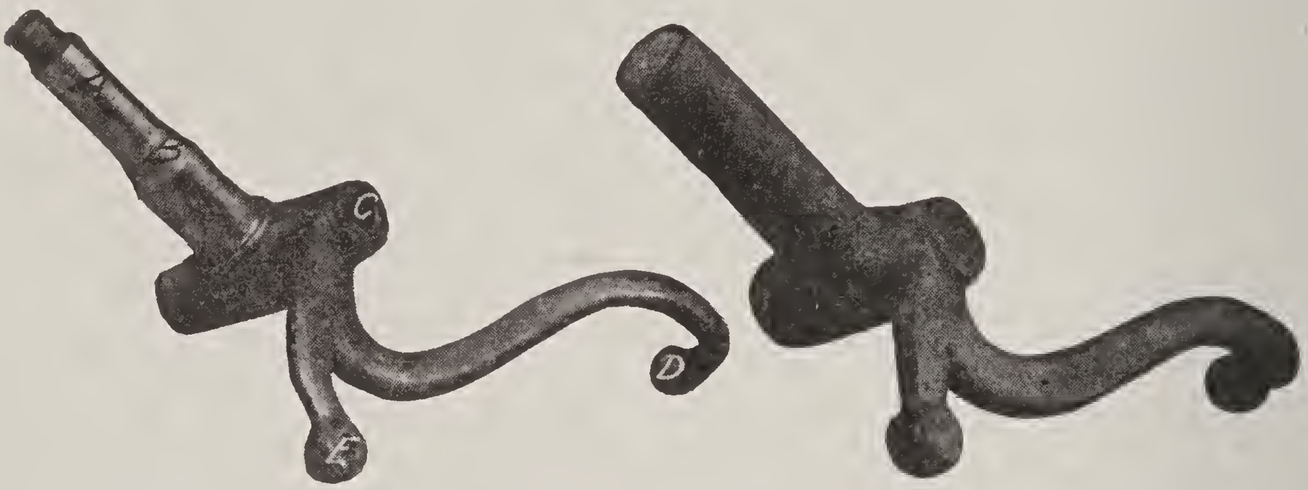


Fig. 343. Finished S.G.V. Chrome Nickel-Steel Steering Knuckle and the Same before Machining

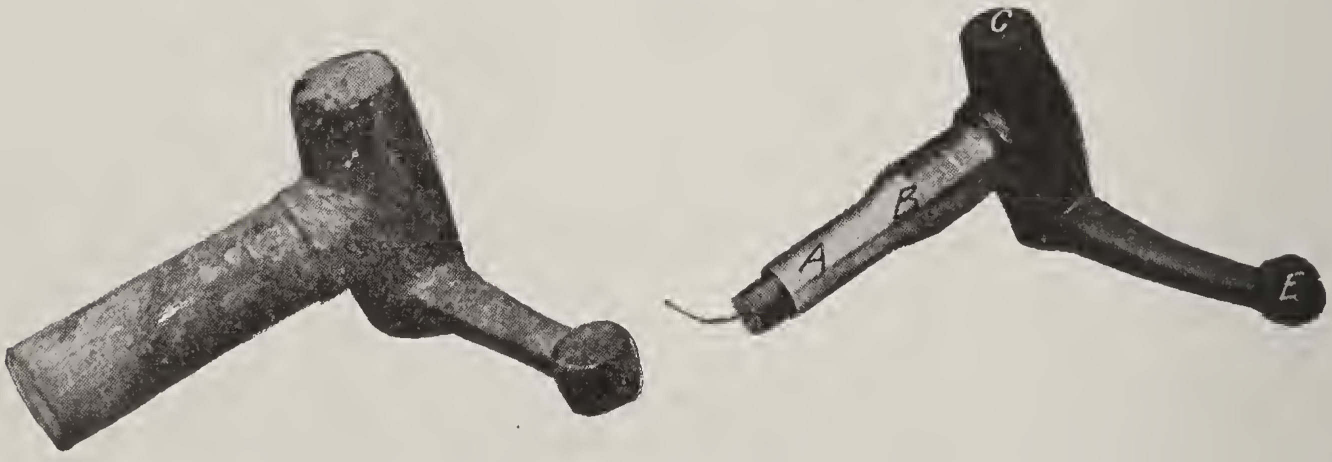


Fig. 344. Left Steering Knuckle of S.G.V. Car before and after Machining

The tie rod is made adjustable to compensate for any change that may be necessary to preserve the alignment of the wheels, and, generally, the rod is adjustable at either end. The yoke ends of the rods are made adjustable, screwing on or into the rod proper and secured by lock nuts or other suitable fasteners. The adjustment is easily made. Decreasing the length of the rod increases the gather, or distance, between the forward section of the front wheels, while increasing it causes the wheels to toe in. This applies to the tie rod behind the axle.

Function and Shape of Steering Knuckles. The steering knuckles serve as a pivot for the road wheels, enabling them to move in a horizontal plane. The design of the knuckle depends upon the axle, and the pair used on a car are different as one has a lever for carrying the drag link. Both have integral spindles to which the tie rod is attached. Figs. 343 and 344 illustrate the difference between the knuckles.

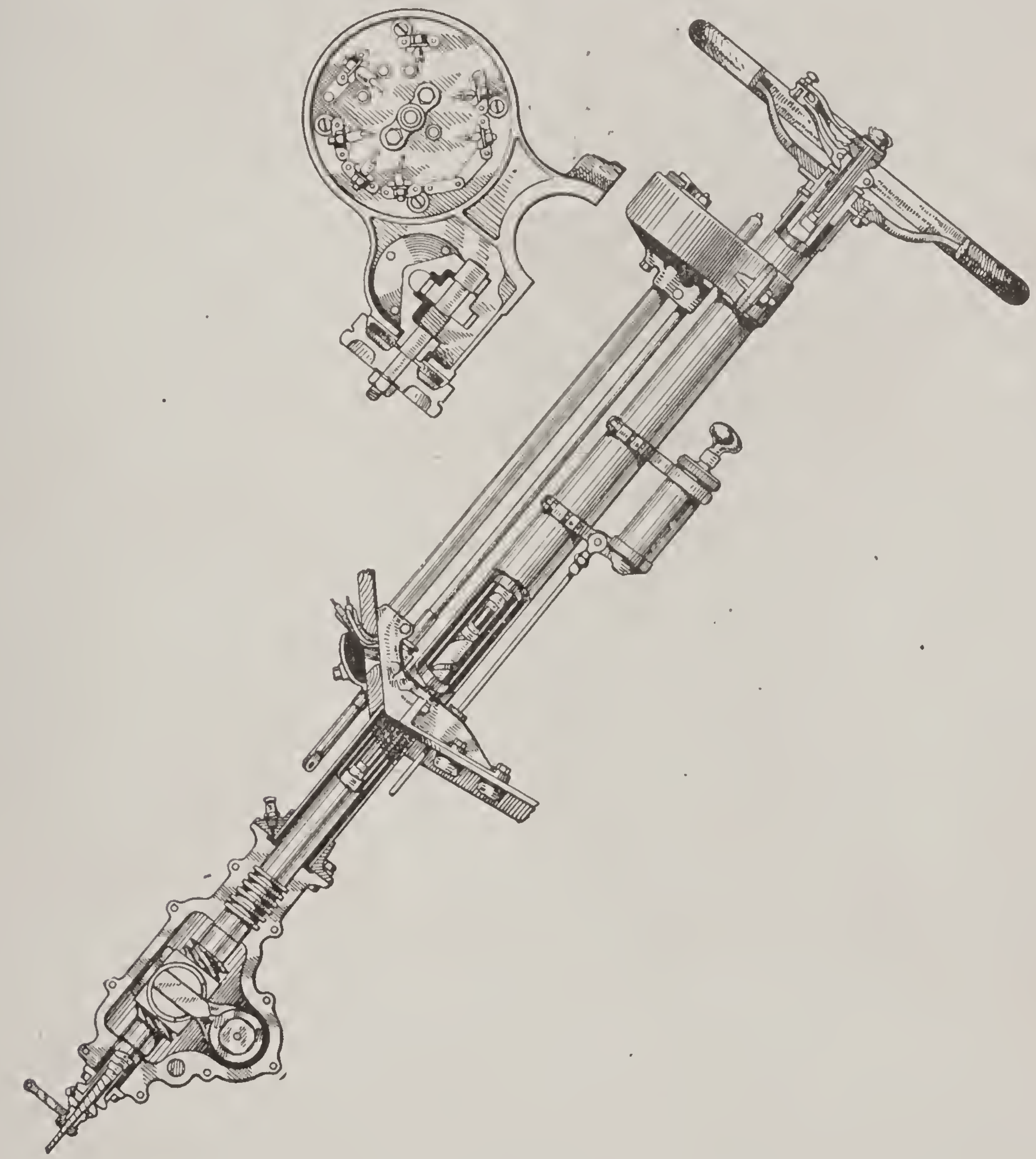


Fig. 345. Packard Steering Gear Parts

Fig. 343 shows a right knuckle, forged from a blank of chrome nickel steel, while the one at its side is the finished part. *A* is the place for the outer wheel bearing, *B* the position of the inner bearing, *C* the hole for the pivot, or knuckle, pin, *D* the upturned steering arm, and *E* the arm to which the tie rod is attached. Fig. 344 is an example of a left steering knuckle of the same pair, both before and after machining. The letters in Fig. 343 apply to this knuckle.

Lubrication of Steering-Gear Assembly. The proper lubrication of the steering-gear assembly adds to its life, but this work is not, as a rule, thorough. The steering gear proper should be packed with grease, the ball and socket joints of the drag link and steering-arm lever with a light grease; the clevis pins also should be lubricated. The steering-knuckle pins are provided with either grease or oil cups.

A point generally overlooked in the lubrication of the steering gear is the steering-post spark shaft and throttle-sector anchor tube, shown in the illustration at Fig. 345, which is of interest in that it illustrates the assembly of the Packard car. The post carries the control-box unit. The spark shaft and throttle tube frequently lack lubricant and should be cleaned and coated with a graphite grease before replacing when the gear is being reassembled. The lower extremity of the spark and throttle members carry levers or small bevel sectors which operate the linkage of the ignition apparatus and carburetor. Clamping screws are generally used to secure these parts.

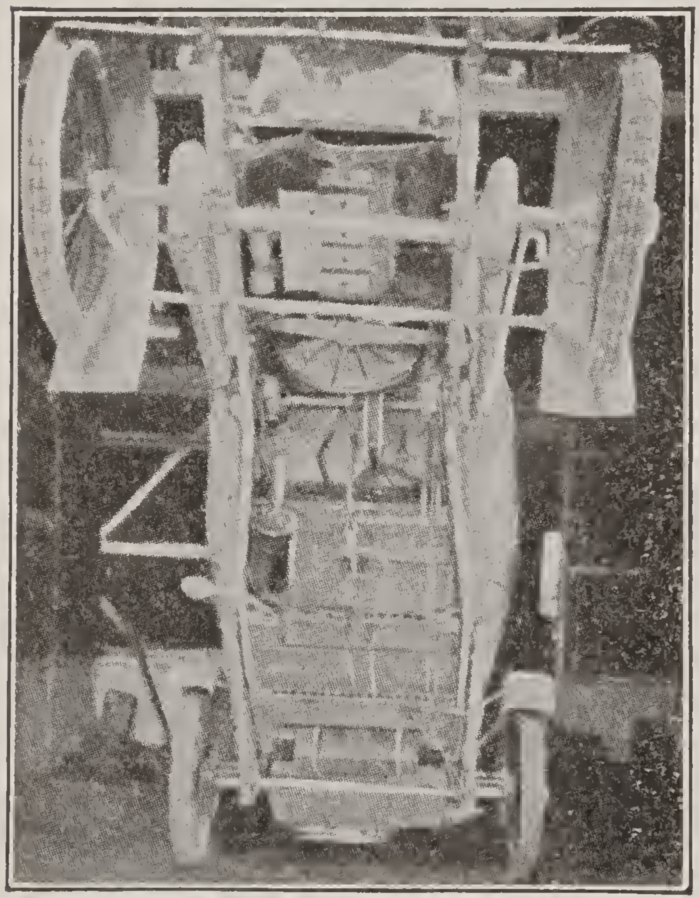


Fig. 346. Front Drive and Steer on Homer Laughlin Car

SPECIAL TYPES OF DRIVE

Front-Wheel Drive. In the conventional type of pleasure motor car, the energy of the engine is applied to the rear wheels which propel the car, the drive being a pushing one. A pleasure car, or rather a racing machine, with a front-wheel drive—which is a pull, and held by some to be more economical—was brought out several years ago but not marketed. During the latter part of 1916, a company was formed to market an eight-cylinder pleasure vehicle, utilizing a front-wheel drive and steer and a friction drive with an automatic pressure control.

Difficulties of Transmission. The Homer Laughlin car, a bottom view of which is shown in Fig. 346, makes use of an original type of universal joint to transmit uniform angular velocity. Its design was brought about by the fact that the rate of transmission of angular velocity through a universal joint is not even when the shafts are at an angle. This is the fundamental difficulty every designer of a front drive has to overcome or suffer the twisting of the axle.

The front wheels and the flywheel must rotate at practically a uniform speed, at least through each revolution. The irregular rate of transmission through the universal joint must be taken up somewhere. The normal action of a universal joint at certain angles is to make four jerks in a revolution, as it has four fast points and four slow points. The Laughlin joint gives uniformity of rotation with 75 per cent on each side of normal, the difference being taken up by the flexibility of the transmission parts.

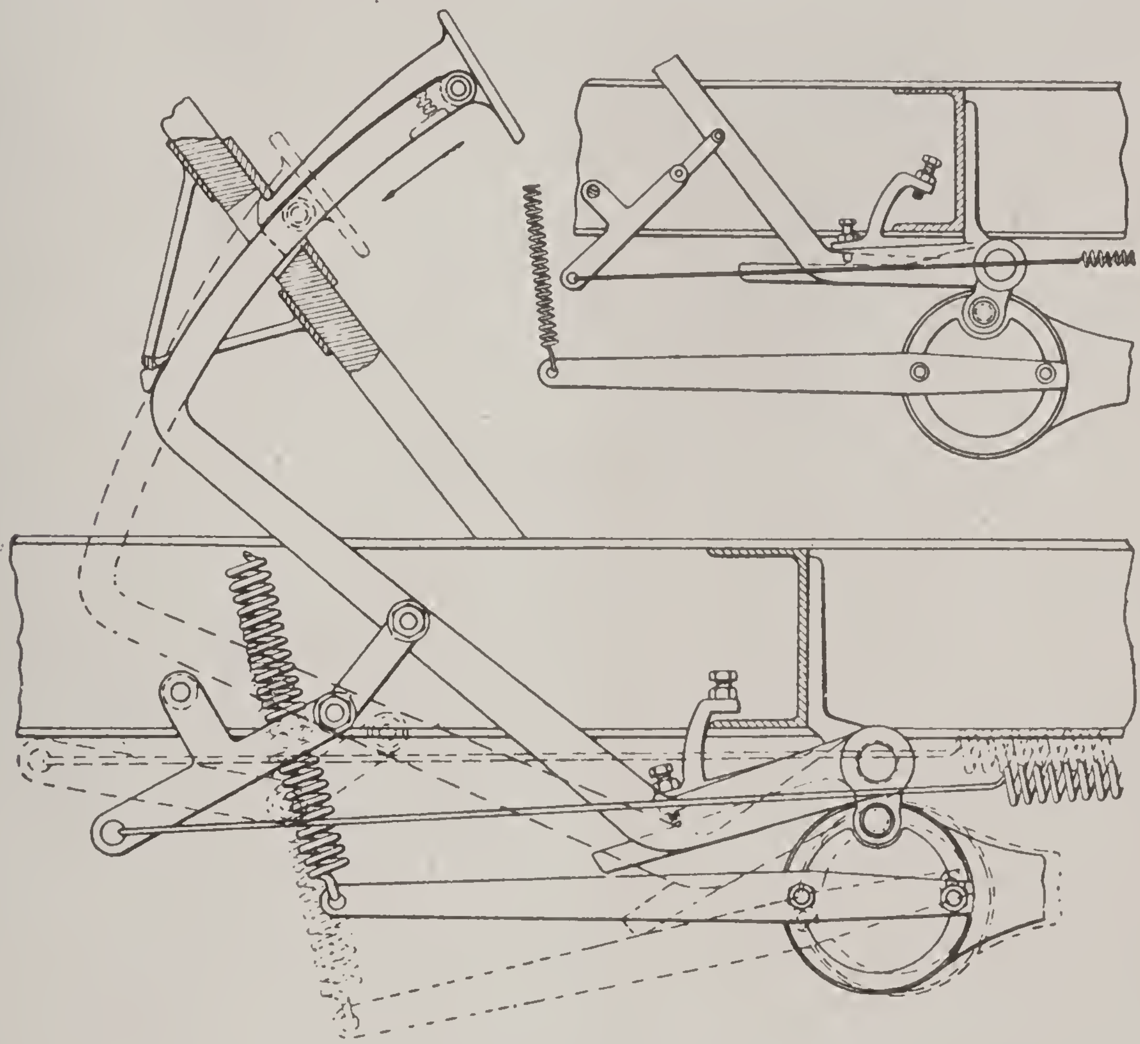


Fig. 347. Homer Laughlin Pedal Mechanism

Friction-Disc Transmission. The transmission is of the friction-disc type, but the disadvantage of this form of drive—the fact that the control is reversed—is eliminated. The usual clutch control is provided, but the pressure is automatic. This pressure is obtained by an eccentric connection by means of which designers obtain irreversible application of spring pressure. The transmission locks at the correct pressure through the friction of the eccentric. The spring controlling the friction for driving provides the proper pressure for running, but it is not sufficient for starting or climbing long hills in the low gear. The pedal shaft operates a dog that presses down on the eccentric sheave extension. To de-clutch, the operator presses the pedal down, releasing the clutch. The pedal has two points at which it latches, providing extra pressure, and an extra spring is brought into service for the high and low speed. This spring operates through a toggle linkage. As the pedal rises, the applied power increases. When the car attains momentum, the driver depresses the pedal until it latches. The running pressure is sufficient to hold the engine in all gears except the low and reverse.

Control. Complete control is obtained through one gearshaft, the lever working forward for progressive, and back for reverse. Automatic latching is obtained in every gear, the latch working in sockets sunk in the jackshaft. Chain drive is employed between the transmission and front axle. The brakes are located on the rear axle. Fig. 347 shows the method of obtaining a conventional pedal control of the transmission through the irreversible application of spring pressure—one spring for ordinary service, the other for low gear work—controlled by the eccentric on the jackshaft of the driving mechanism.

Four-Wheel Driving, Steering, and Braking. The four-wheel drive—a construction in which all four wheels of the vehicle drive, and frequently steer and brake—is confined to commercial vehicles. A brief consideration of the actions which may have to take place at the same time in such an axle will give a very good idea of the problem which must be worked out. The wheels must be free to turn about the axle as an axis, being driven from their hollow centers; the wheels must also be free to turn about the pivot point as an axis swinging in a horizontal direction and must be driven steadily all the time. All the turning, swinging, and driving action must be outside of and beyond the spring supports of the chassis, since the body cannot turn; but the axles must at the same time support the springs. Further, if all four wheels are to carry brakes, they must be applicable at any and all times and at any and all angles of inclination of the wheels, either in a vertical or horizontal direction, and they must be so equalized as to apply equally to all wheels, no matter how the force is applied to the system, and no matter in what position the wheels may be.

The advantage of the four-wheel drive and with it the four-wheel steer and brake is granted by eminent engineers, as is also its necessity for heavy commercial trucks, but its use has not been extensive for the simple reason that it is a complicated arrangement at best. In many cases, the design has been so complicated and unmechanical as to cause failure, and the reports of these troubles have given the four-wheel driving, steering, and braking device a sort of visionary air, so that any one talking of it is supposed to be a dreamer. Such is not necessarily the case, for many different practical four-wheel combination driving, steering, and braking devices have been brought out, built, tested, and proved efficient.

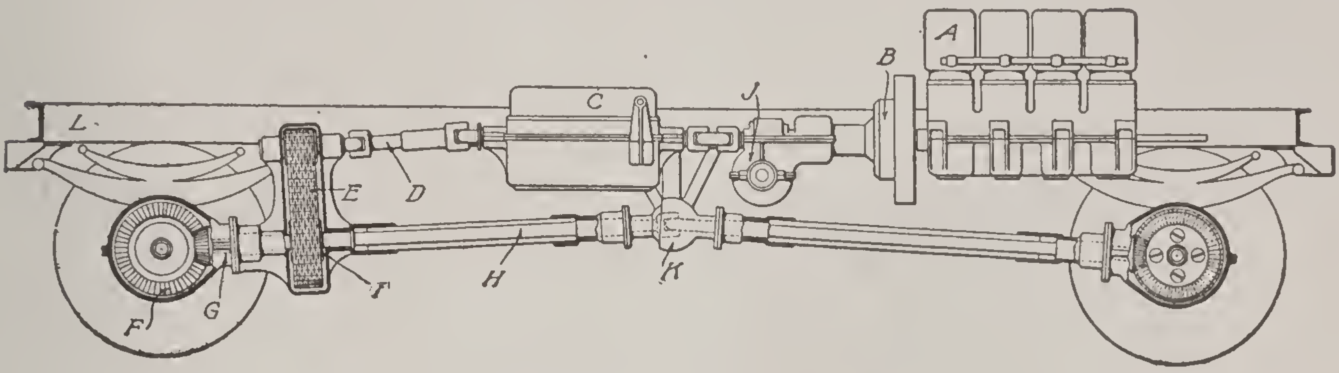


Fig. 348. Side View of a Four-Wheel Drive, Steer, and Brake Motor Truck

A number of four-wheel designs for commercial cars are being marketed, and have proved the contention of their makers that they are economical in operation and maintenance.

Four-Wheel Steering Arrangement. With the design shown at Fig. 348, steering knuckles are eliminated, the wheels being connected to the axle ends through the medium of vertical trunnions. These trunnions bear on the wheel ball-bearing ring, which is ample in diameter and turns freely because of its size and the use of ball

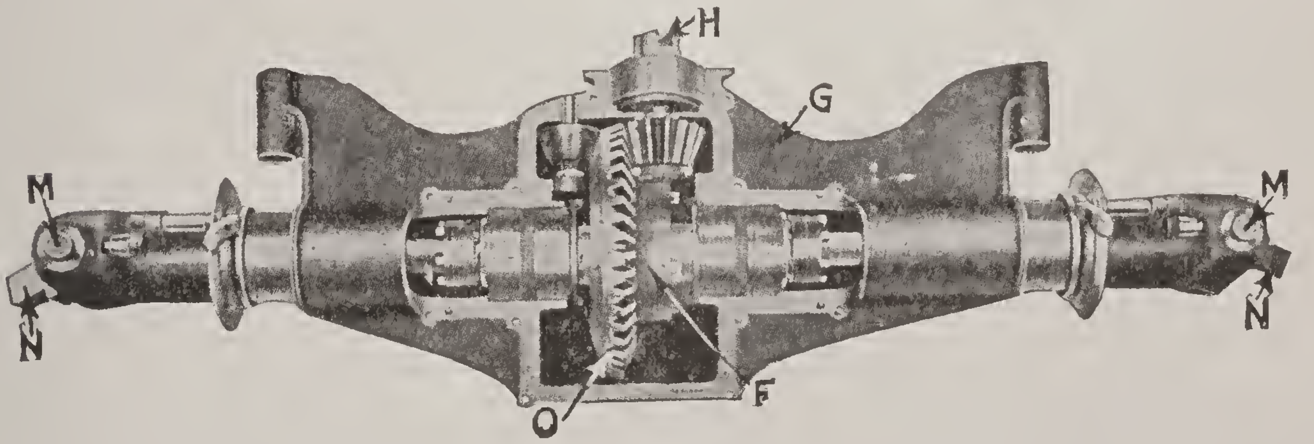


Fig. 349. Details of Axle of the Four-Wheel Drive Truck Shown in Fig. 348.

bearings. Within this ring, the axle terminates in what is practically a universal joint, driving through to the outside of the wheels. The wheels are thus free to run about a point in the axle ends, at the same time taking their power through the inside rotating shaft. Fig. 349 illustrates one of these axles with the parts lettered. Here *H* is the point of attachment of the driving propeller shaft, *G* the cast-steel one-piece case, *F* the differential gear within the large driven bevel gear *O*, *MM* the vertical trunnions upon which the wheels rotate, and *NN* the universal joints which drive the wheels.

How the steering is obtained is shown in Fig. 350. At the front of the chassis is the steering wheel *P;* turning it partially rotates the longitudinal shaft *Q*, which extends the length of the chassis. This shaft carries levers *RR* near its two ends, which are connected to the steering rods *SS*. These rods connect to the steering levers *UU*, which are fixed to the wheels themselves instead of to the steering knuckles as in the ordinary case, for this car has no steering knuckles. In addition to the steering rods attached to the longer of the two steering levers, there is a cross-connecting rod *TT* at each end, which connects the two steering levers. Thus, when the levers *RR* move the rods *SS*, and through these the levers *UU*, which in turn move the wheels *VV*, the rods *TT* also come into play and move the levers *WW* and the wheels *XX*. Therefore, the movement of the steering wheel in any given direction, as to the right, turns all four wheels, the front two to the right, and the rear two to the left so that they form arcs of the circle in which the front ones are turning. The truck thus makes the desired turn to the right in one-half the

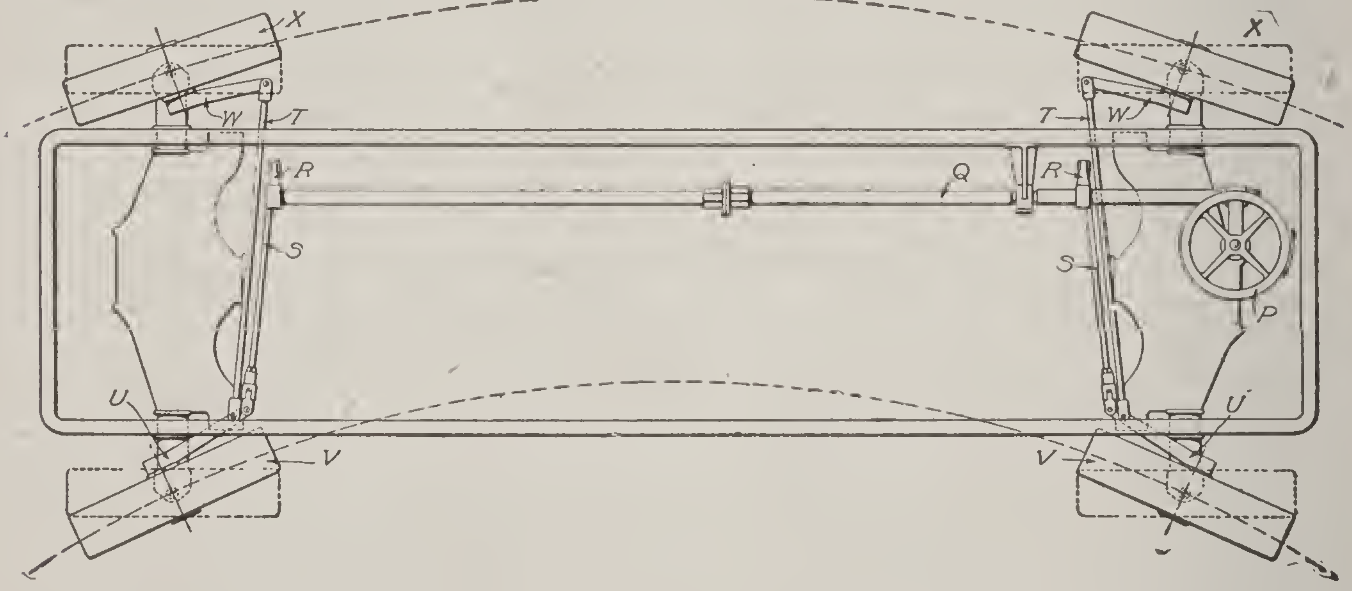


Fig. 350. Diagram Showing Steering Action of a Four-Wheel Drive Truck

distance or time of the ordinary truck. Four-wheel steering then has the advantage over two-wheel, or ordinary, steering, of requiring only one-half the space and one-half the time to accomplish a given turn. The vehicle described would turn completely around in a circle of 40 feet, the outermost circle shown in Fig. 350 being 56 feet in diameter.

Chain Four-Wheel Drive. Fig. 351 clearly illustrates a bottom view of the Hoadley four-wheel drive, four-wheel steer, and four-wheel brake truck. The power of the engine is transmitted through shafts, gears, and universal joints to the differentials; there is a third differential in the gear box at the center of the frame. Final drive is by chain; both ends of the truck are exactly alike in so far as the four-wheel drive is concerned, and the fifth wheels run in ball bearings. Steering is accomplished by means of worm gearing, the shaft being clearly shown, and both sets of wheels are steered simultaneously.

Jeffery Quad. An example of the successful development of the four-wheel drive is the Jeffery Quad, Fig. 352, which has given an excellent account of itself in government work. In this type it will be noted that the inclined driving shafts, shown in Fig. 348,

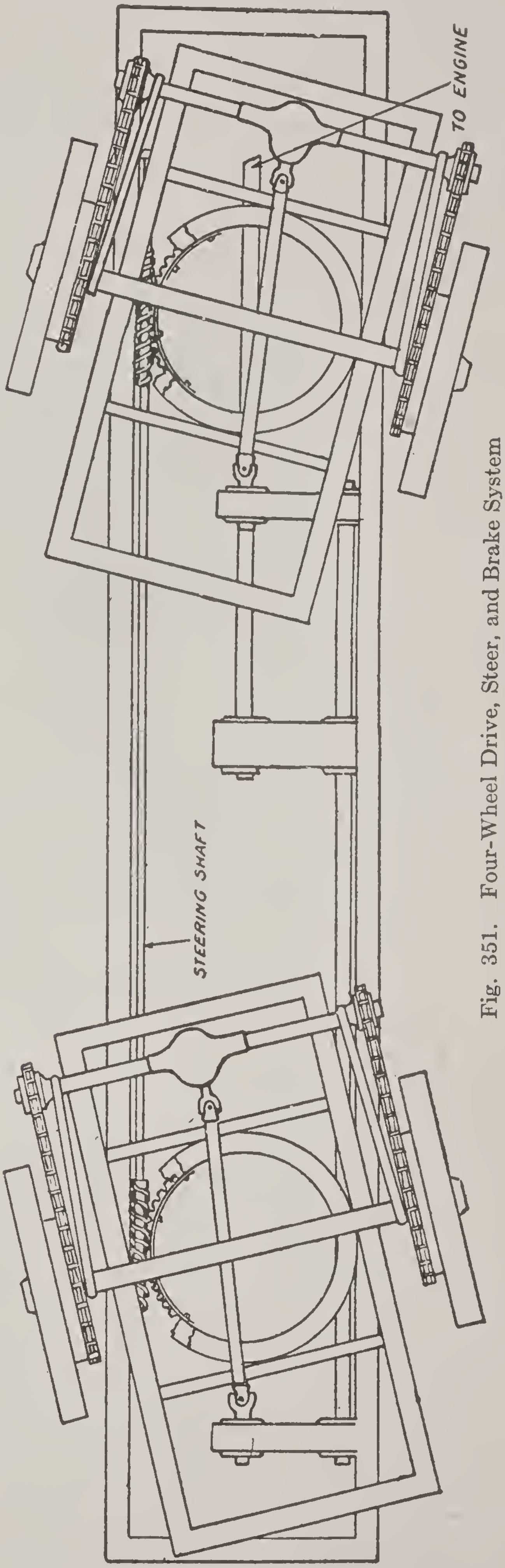


Fig. 351. Four-Wheel Drive, Steer, and Brake System

have been carried up to the gear box with a universal joint on either side. This construction has resulted in a much more inclined shaft in each case, but it has also eliminated the tail shaft *D*, the use of a silent chain *E* with its housing, the central universal joint, and the spherical bearing *K*, and, in addition, it has simplified both shafts.

In the four-wheel drive vehicle the engine was placed on the center line of the car; on the Jeffery it is set off to one side, while the two driving shafts to the front and rear axle, which form a continuation of each other, are set off to the other side. This result is produced by making the transmission very wide with three side-by-side shafts, as shown in Fig. 353. The engine drives the splined shaft *H*, on which are gears that transmit the rotation to the intermediate shaft *C*, which through the final gears *E* and *F*, drives the final shaft, which is in two parts, *B* driving one pair of wheels, *G* driving the other pair. Note that the differential has been incorporated in this type of drive, so that it is possible to have a different drive for the front wheels from that for the rear wheels.

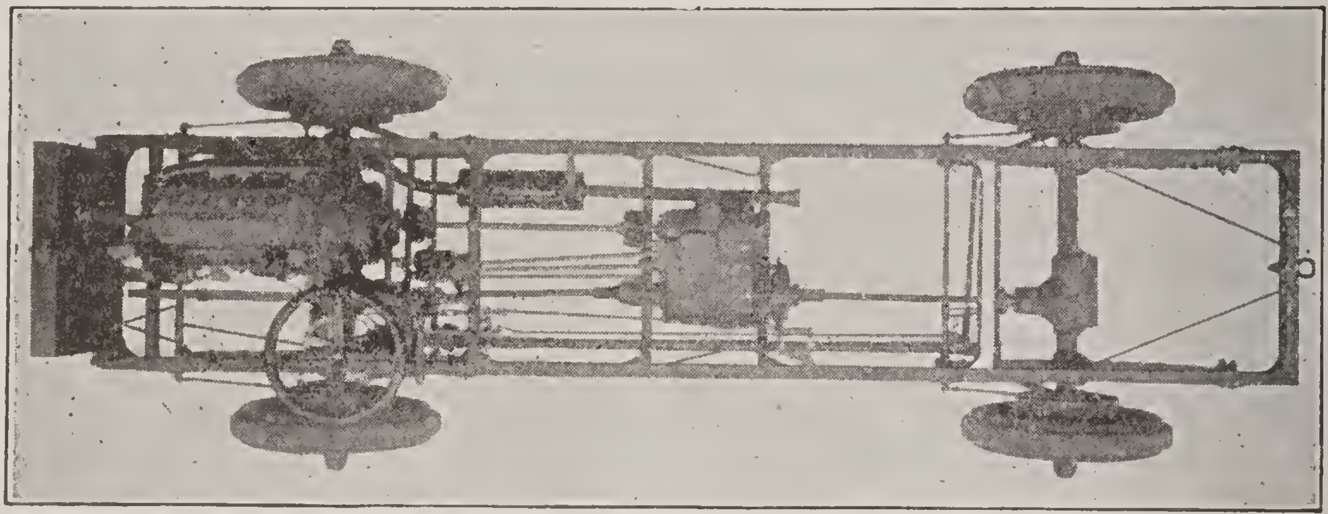


Fig. 352. Plan View of the Jeffery Quad, Showing Disposition of Units
Courtesy of Thos. B. Jeffery Company, Kenosha, Wisconsin

The rest of the construction is too simple to require a detailed description beyond the simple statement that the gear box gives four forward speeds and one reverse. When the two ordinary shifters are in the neutral position shown, reverse is produced by shifting the double reverse gear on shaft *D* along until its left-hand member meshes with the second-speed gear on shaft *A* and its right-hand member with the low-speed gear on shaft *C*.

Universal joints fit on the two tapers *B* and *C* with shafts inclined to the two axles. On top of the stationary axle of the I-beam section is fixed a small box which contains the bevel gears and an additional differential with suitable bearings, the whole being enclosed. These can be seen in Fig. 352, that on the rear axle being plainly shown, while the one in front is partly obscured. This member is shown in detail in Fig. 354, which gives the longitudinal section along the driving shaft at the left, in which the axle *H* is noted, the bevel gear *I*, and the bearings for radial and thrust loads at *J* and *K*, respectively. The driven shaft is seen at *L*, with the sleeve *M* around it, the sleeve being used to drive to the differential case, since the larger, or driven, bevel *C* is not sufficiently large to house the differential *P*.

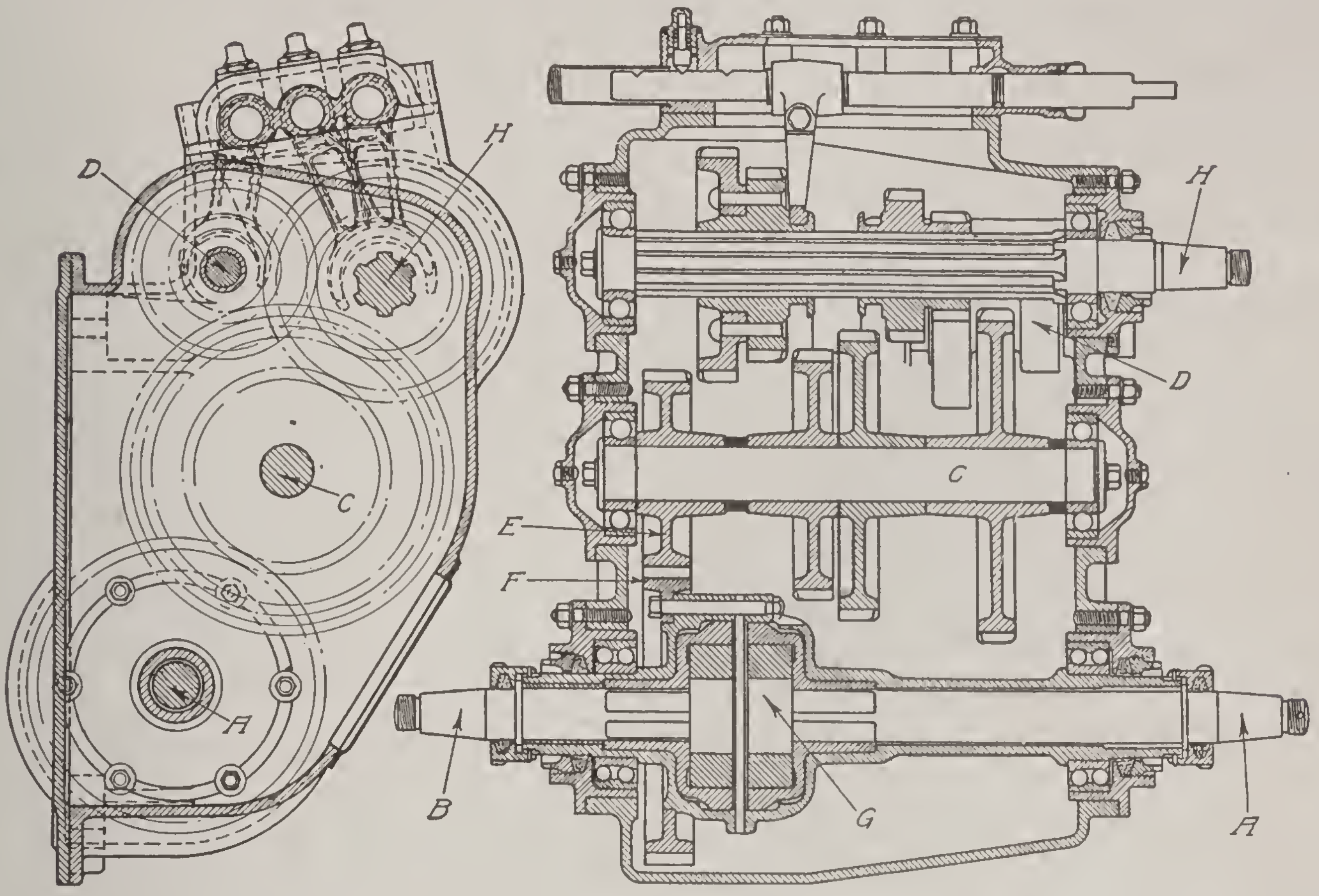


Fig. 353. Plan View of the Transmission of the Jeffery Quad, Showing the Shafts for Both Axles

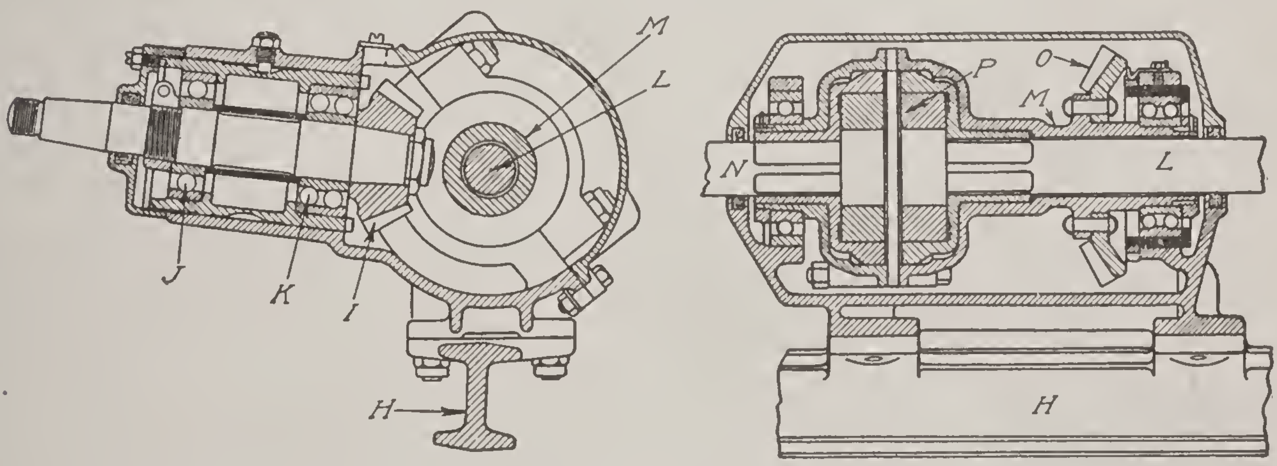


Fig. 354. Sections Showing Bevel Drives at the Axles on Jeffery Quad

Fig. 355 is a diagram showing the details of the axle end and wheel construction. In this, *H* is the I-beam section of the axle bed shown in Fig. 352, and *N* one of the shafts, which carries at its end the universal joint *Q*, with the end of the shaft extending beyond the joint *R*. The latter carries the spur gear *S*, which meshes with the internal gear *T* fixed to the wheel and drives the vehicle in this manner. It will be remembered that this is not necessarily a front wheel, but any one of the four.

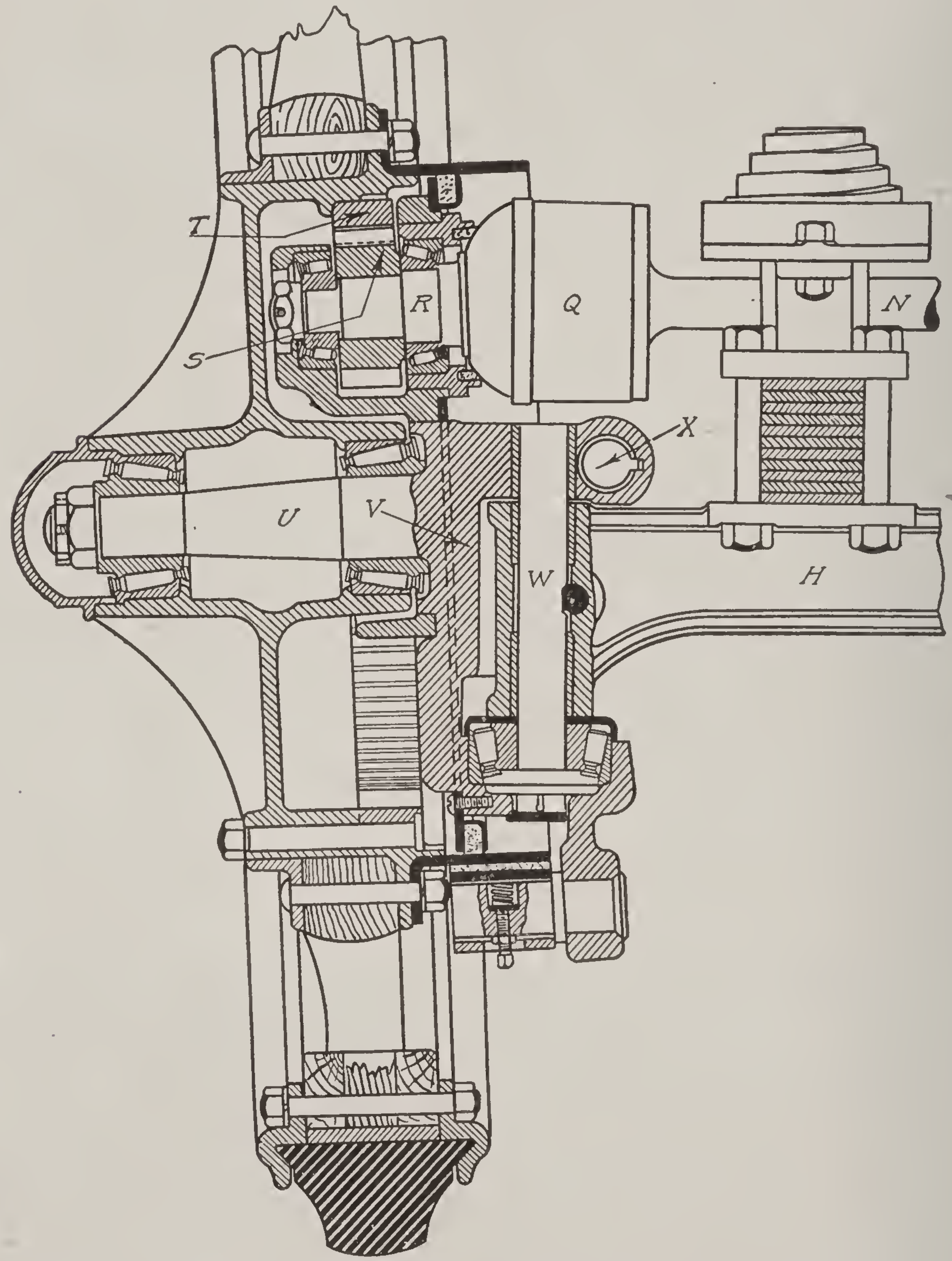


Fig. 355. Section through a Wheel and Axle End of the Jeffery Quad, Showing Method of Driving and Steering

The wheel turns on the spindle *U*, which is part of the steering knuckle *V*; this knuckle turns upon the pivot *W*. The lever which turns the wheel is attached at *X*, the pair (either both front or both rear wheels) being connected by means of a cross-rod; at one end of this rod there is a connection to a rod which runs the entire length of the chassis. This rod is operated by means of the steering gear, and imparts the same motion to the front wheels as to the rear, except that the two are in opposite directions, that is, front wheels turn to the left and rear wheels to the right, so that they will follow around in a correct circle.

Advantages of Four-Wheel Drive. It is claimed for the four-wheel drive that its four-wheel steering reduces the mileage traveled to the minimum in that the car can run closely to corners and travels less in crowded traffic, in turning around, and in approaching and leaving loading platforms. The push of the rear wheels and pull of the front wheels enables it to surmount obstacles instead of bumping over them, and its greater traction permits it to travel soft roads not easily negotiated by the rear-drive type of trucks and cars. The four-wheel drive type will turn in a 48-foot circle, and, with its locking differential, obtains traction on slippery roads.

Electric Drive. When the final drive is electric, or when the source of power is an electric motor, the matter of four-wheel driving is much simplified, the wheel carrying the electric motor attached directly to it and turning with it about the knuckle pin. Both wheel and motor are turned by means of a worm and gear above, the wheel being attached to the upper end of the steering-knuckle pin prolonged. Turning this turns the wheel and motor.

This steering wheel is turned by the worm, which is on one end of a cross-shaft. This shaft is carried in bearings above the stationary bed of the axle and has near the center a bevel gear that meshes with another bevel, which is, in turn, attached to the lower end of the steering post. Turning the steering wheel turns the post and the bevel gear, which turns the bevel pinion and with it the worm shaft. The shaft turns the worm and the worm wheel which actuates the road wheels. The driver thus has a triple reduction between himself and the wheels, giving him this much advantage in steering: there is the leverage of the wheel of large diameter, the ratio of the sizes of the two bevels, and the ratio of reduction of the worm gearing, which, in addition, is irreversible. The steering gear is thus eliminated and four simple gears substituted for it.

Couple-Gear Type. In the Couple-Gear wheel, which is an American product, the motor is placed inside of the wheel—a type especially designed and constructed for this purpose. With the motor in this position, the wires enter through the hollow hub, altering its construction very materially. As compared with the electric motor on each wheel, previously described, this form has the advantage of greater simplicity, fewer parts, superior appearance, and protection against the elements, while the enclosed position of the motor, which is the most delicate part of the machine, protects it against road obstructions and accidents. This arrangement also simplifies the steering problem, since the car is steered just the same as any other truck, much of the complication incident to an electric motor on each wheel being eliminated.

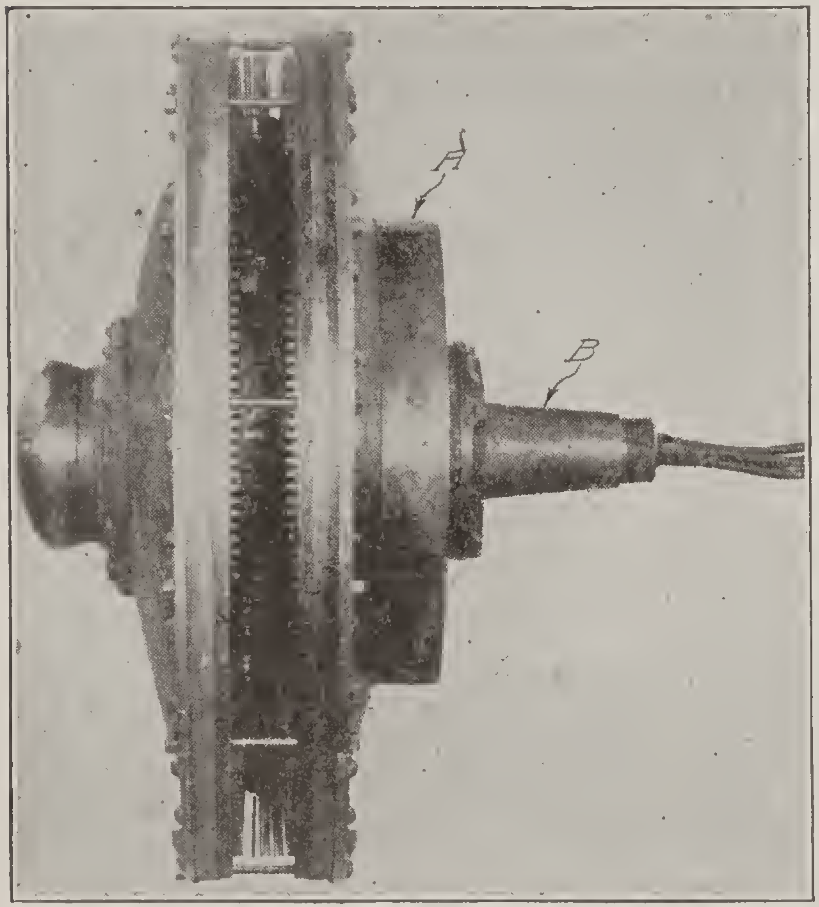


Fig. 356. End View of Couple-Gear Electrically Driven Wheel with Tire Removed

Fig. 356 is a view of the wheel with the tire removed and the whole disconnected from the axle ends. Aside from this, it is complete and ready for use. Note how the axis of the motor is set at a very slight angle, just sufficient to allow a pair of very small driving gears at the two ends of the armature shaft to drive on opposite sides of the wheel. The wheel is assembled with a pair of driven gears on either side, these being separated a comparatively small distance, about 2½ to 3 inches. As stated, the armature shaft has a small bevel pinion on each end, each of these meshing with the driven gears, but on opposite sides. It is this arrangement which gives the device its name of Couple-Gear. In this figure the brake band has been removed, but the brake drum will be seen just inside the wheel at *A*. Beyond this is noted the spindle *B*, which is made hollow for the wires from the battery and turns in a bearing on the axle.

In the second illustration, Fig. 357, an axle, either front or rear, with the wheels removed, is presented. In this cut the left wheel is entirely removed, but the one on the right shows the axle spindle *B*, the method of fixing it in the axle support at *C;* the armature housing *D* is normally within the wheel and not visible. One feature peculiar to this arrangement is the steering, which is effected by means of a vertical post with a small spur gear at its lower end *E*. This meshes with a curved rack *F*, which is machined on the outside of a pivoted member *G*, to which a pair of arms are attached. One of these arms *H* has a rod *I*, which runs to and operates the right-hand spindle *B*, while the other *J* has a similar rod *K*, which operates the left-hand wheel. When all four wheels are to be driven in this manner, the post is vertical, but the connection with the rack *F* becomes horizontal, with a continuation to the rear axle which operates the various arms, levers, and rods there in the same manner.

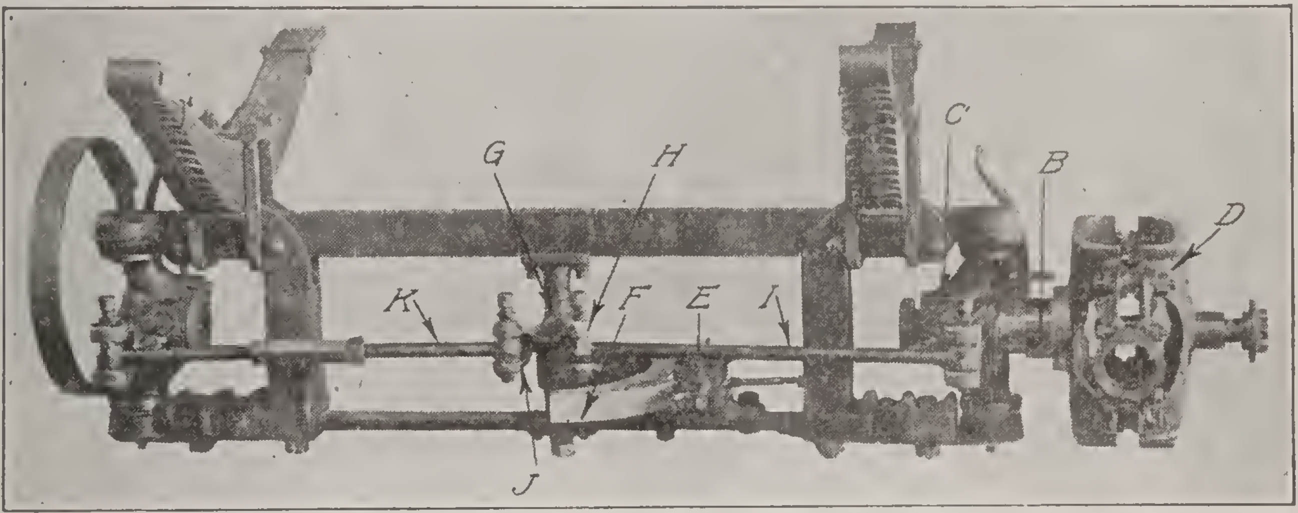


Fig. 357. The Couple-Gear Axle and Parts, Showing Method of Operation
Courtesy of Couple Gear Freight Wheel Company, Grand Rapids, Michigan

This particular system is used for heavy commercial work only, and in this it has been particularly successful as a tractor, a front axle and a pair of wheels being substituted for those of a heavy trucking wagon. Then, with a sling under the body or beneath the driver's seat for the batteries, and with proper wiring, control levers, and steering wheel, the truck becomes electrically driven.

FRONT AXLES

TYPES

Classification. Generally speaking, front axles may be divided into about five classes: the Elliott, the so-called reversed Elliott, the Lemoine, the front-drive form, and the fifth-wheel form.

These typical forms of axles are themselves subject to further subdivisions. For example, there are many different forms of Elliott axles, each manufacturer having what is practically his own form. Again, the Lemoine, when used by other firms, has been built in a practically new form, taking the second maker's name. Thus the form of front axle made by Lemoine for Panhard is so different as to be called the Panhard, and not the Lemoine. The same is true of the Lisses axle made by Lemoine. In this country, it is claimed that the axles made by Timken are sufficiently different from the Elliott and reversed Elliott, from which the principle was taken, as to deserve the name of Timken axles. It should be borne in mind that in the following description of the various axle types the forms of material, and the shape, size, and kinds of bearings used do not alter the principle upon which the axle is constructed, although they do alter the appearance.

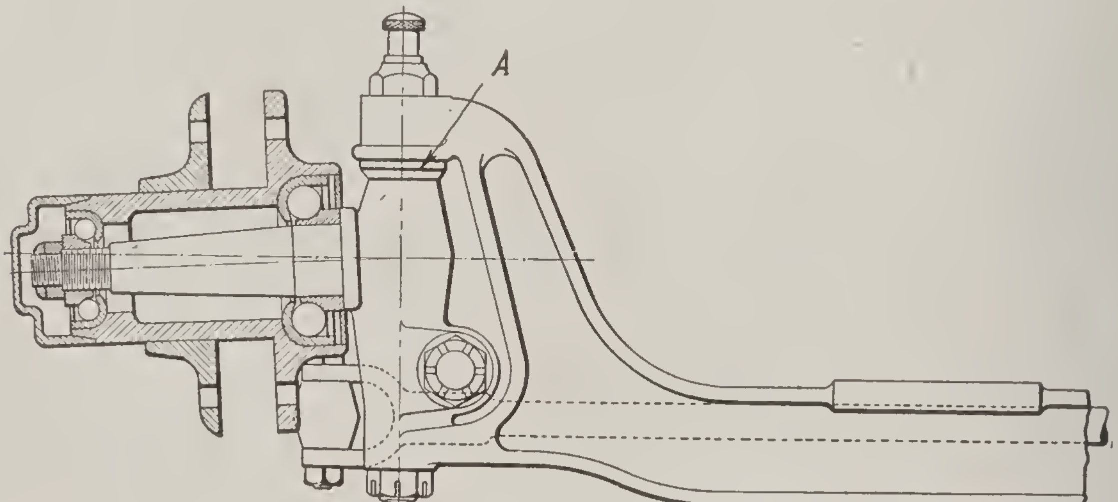


Fig. 358. Elliott Type of Front Axle and Steering Knuckle

Elliott Type. In general, a front axle consists of a bed, or axle center; a pivot pin or knuckle pin upon which the knuckles may turn; and the knuckles themselves with the attachment for turning them. The Elliott type, Fig. 358, the form in which the end of the axle takes a U-shape, is set horizontal and goes over the knuckles. The knuckles have plain vertical ends bored for the pivot pin, which passes through and has its bearing in the upper and lower halves of the axle jaw. In this form, the thrust comes at the top, where the axle representing the load rests upon the top of the knuckles that represent the point of support.

Reversed Elliott Type. In the reversed Elliott front axle, as the name would indicate, the action is just reversed in that the axle end forms a straight vertical cylindrical portion bored for the pivot pin, while the knuckles are so formed as to have jaw ends which go over the axle ends. The thrust comes at the bottom of the knuckle, where the axle bed rests upon the upper face of the lower jaw of the knuckle, the axle representing the load and the knuckle the support, just the reverse of the previous case.

This will, perhaps, be made clearer by illustrations. In Fig. 358, as already mentioned, the axle has the jaw ends, and the thrust comes at the top. This is indicated in the figure by the letter *A*, which calls attention to the thrust washers at the top. Fig. 359 shows an axle of the reversed Elliott type, this being the front axle for a heavy truck. In this the thrust washers *A* are at the bottom, and are of hardened steel, ground top and bottom to a true surface; the upper surface is doweled to the axle, while the lower is doweled to the knuckle. This form has the real advantage of concentrating all of the difficult machine work and assembling it into one piece, the knuckle. The Elliott type, on the contrary, makes the knuckle and axle difficult pieces to handle in the machine and afterward, this being shown in the cost. Ease of machining the bed of the axle is a great advantage, for the axle will average about 44 inches in length for a standard tread of 56½ inches, and longer for wider treads, up to a maximum of about 48 inches for the wide-tread standard in the South.

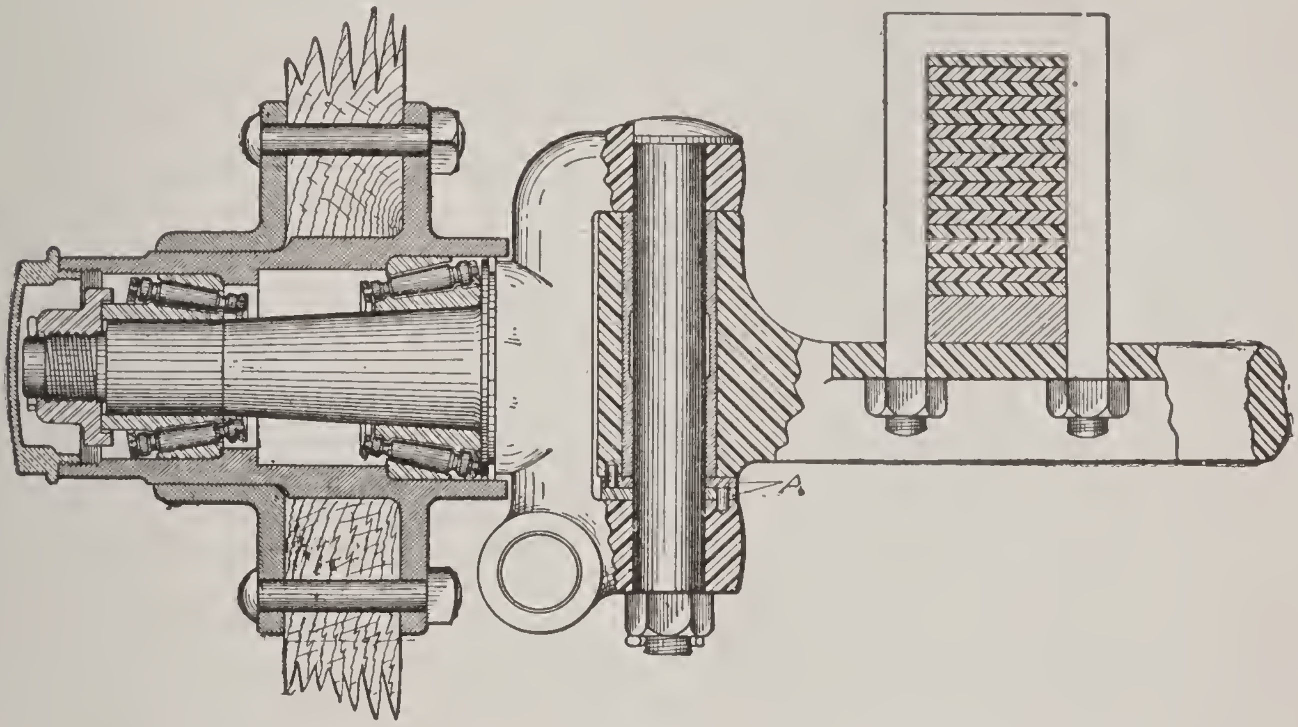


Fig. 359. Reversed Elliot Type of Front Axle and Steering Knuckle

The ordinary automobile machine shop is not fitted up for work of this size, particularly in machine tools other than lathes, and this job could not be done on a lathe. The result is that it becomes a task to handle it, necessitating special and expensive rigging for that one job. This was the case with the axle shown, a boring mill of the horizontal type and a large size milling machine being used on it. Both of these had to have special fixtures, which were useless at other times, to hold and machine these parts. At that, this job was much easier than an axle of corresponding size in the Elliott type would have been.

Lemoine Type. The Lemoine type of front axle differs from those described in that the axle proper bears upon the top or bottom of the knuckle-pin part of the knuckle, the two being made as one; that is, an extension or a jaw of the axle does not support the knuckle as with the Elliott type. When the steering knuckle of the Lemoine type is mounted below the axle stub, the latter is carried higher than with the reversed Elliott, so as to rest upon the top of the knuckle. An advantage of the construction from a manufacturing viewpoint is the cost of machining. With this design, the thrust load is practically entirely at the bottom upon the knuckle, which also must take all side loads; it is fastened in a sidewise direction at but one point—the bearing in the axle. The side shocks are taken on the end of a beam fixed only at the other end, whereas with the other types, the load is distributed between two supports, or divided equally over two sides, the point of support being midway between them. With the Lemoine type discussed, the bottom bearing must compensate for radial and thrust loads—a difficult condition to meet.

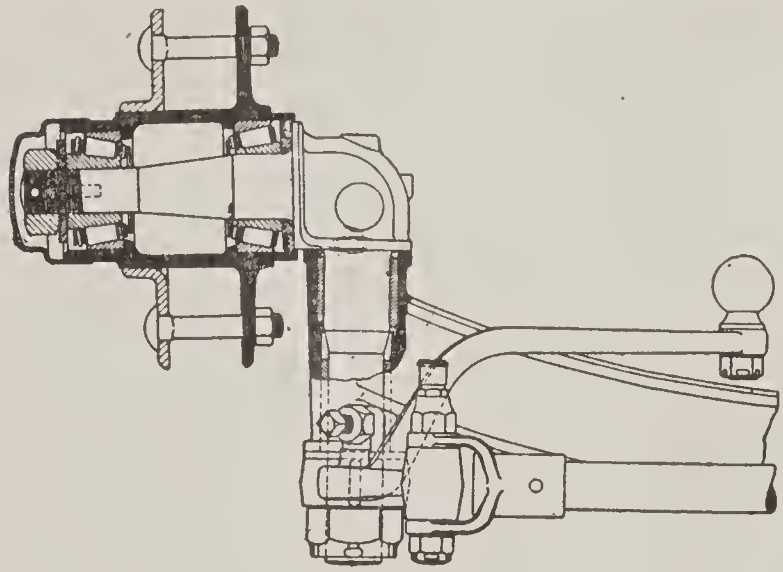


Fig. 360. Inverted Lemoine Type of Axle as Used on Overland Cars

While the design is easy to machine, assemble, and handle, its disadvantage is that the knuckle has a double duty, having, as it does, both radial and thrust loads to care for because of its one-piece construction. This type of axle is, however, very popular with foreign designers.

Inverted Lemoine. A novel type of axle has been created in the 1916 Overland car, Model 75, called an inverted Lemoine. In this type, as Fig. 360 shows, the wheel spindle, or stub axle, is at the top of the steering knuckle instead of at the bottom as in the case of the regular Lemoine type. The knuckle has a single, fairly long support in the end of the I-beam front axle, the forging being much simpler on this account. In fact, this makes the axle nearly straight, which doubtless accounts in large part for this unusual design. One real advantage of this design is that it allows the car weight to be low in relation to wheel bearings, thus assisting in steering.

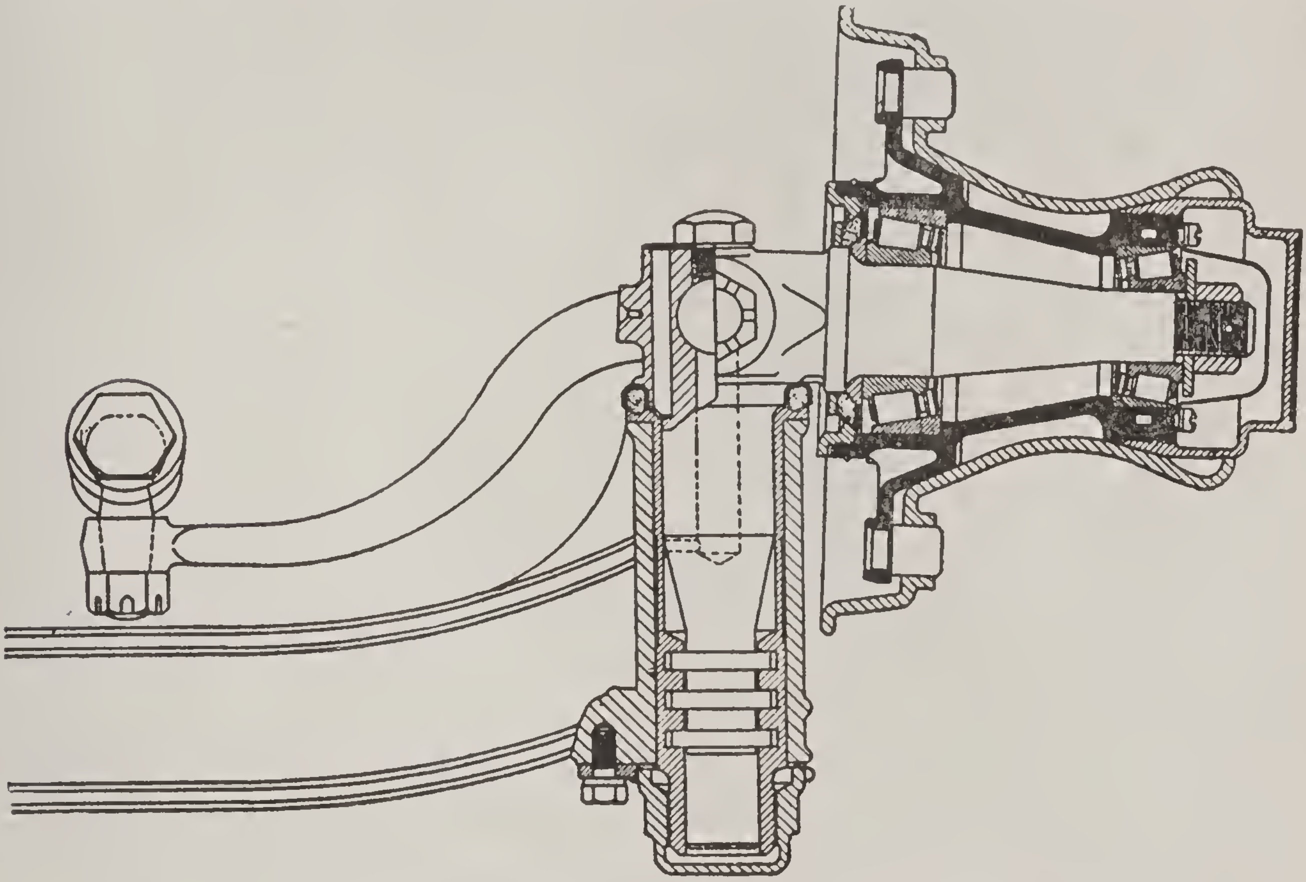


Fig. 361. Novel Front Axle Design Used on the New Light-Weight Marmon
Courtesy of Nordyke and Marmon Company, Indianapolis, Indiana

Marmon Self-Lubricating Axle. The new Marmon front axle, Fig. 361, is of the inverted Lemoine type similar to the Overland, shown in Fig. 360, but at first glance it looks quite different. For one thing, the bearing in the axle end is different, and in this lies an exclusive and valuable feature. The stub-axle pivot pin, made integral with the stub axle, is placed in a split bushing, which is a tight fit at the bottom—where the thrust collars are formed in it—and at the top, but not in the middle. When this bushing is in place, the knuckle and bushing are forced into the axle end from above, and a kind of hub cap screwed on at the bottom. This holds it permanently in place.

Near the middle of the split bushing there is a narrow slot to which a central bolt hole is connected. On being assembled, the inside is filled with lubricant, which cannot escape; but, as it wears away, the central bolt can be removed, more lubricant can be poured in until it is full, and the bolt replaced to prevent leakage. In this way the axle is self-lubricating, and, as the oil is used up very slowly, it needs practically no attention.

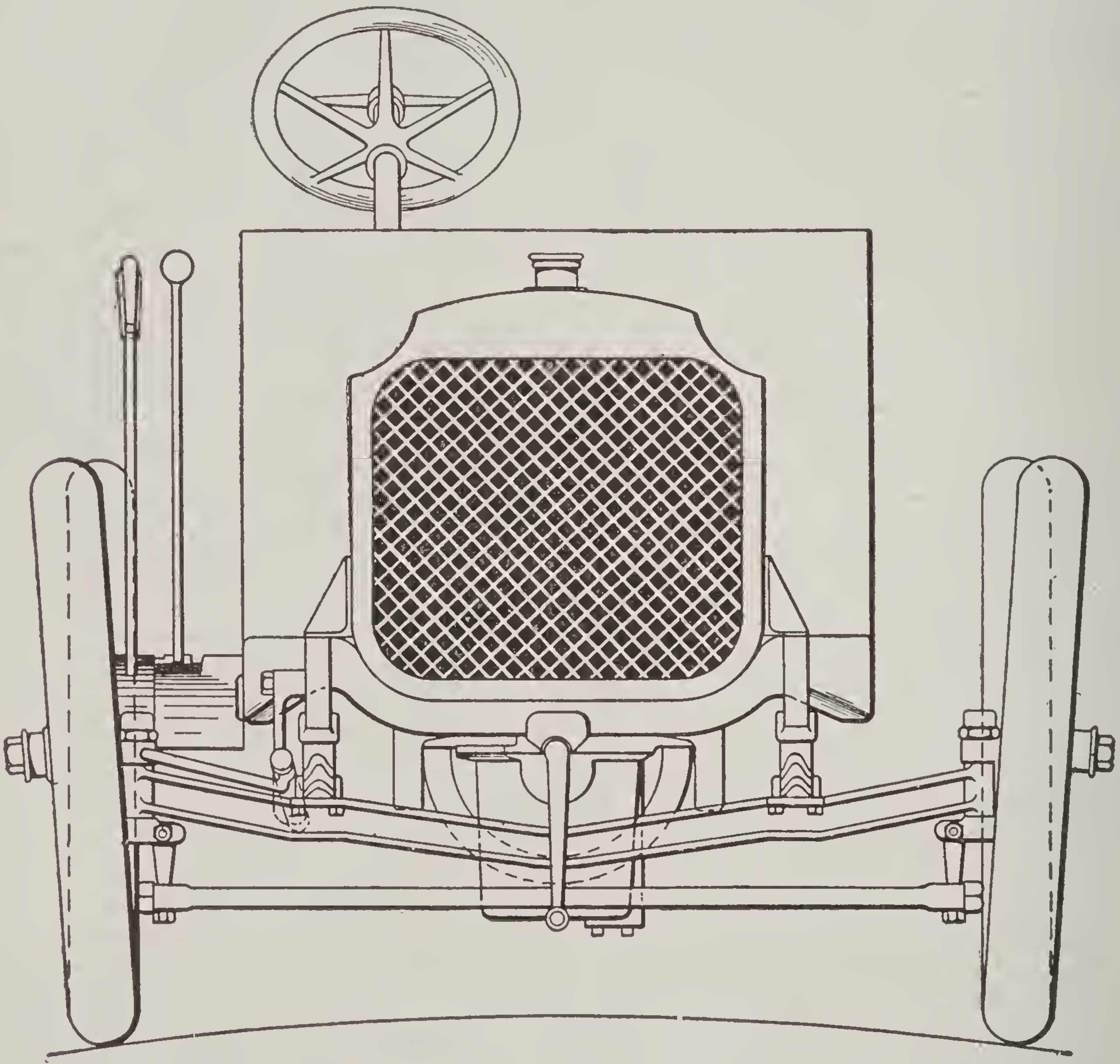


Fig. 362. Front Elevation of Car, Showing Camber of the Front Wheels

Like the Overland, this arrangement of the axle end brings the axle down low, relative to the weight, and consequently steering is made easier. The lowering of the axle also brings the points of spring support down and thus lowers the whole car.

Camber Somewhat Complicates Axle Ends. All front wheels are dished, that is, the spokes do not lie in a flat plane but in the form of a cone, with the point of the cone at the outer end of the hub and the base of the cone at the rim of the wheel. Now all roads and most all pavements are made with a camber. The center of the road is made higher than the sides so that the road will drain. It is necessary, in order to have the lower spokes plumb or perpendicular to the road surface, to throw the center line of the wheel out of the vertical plane 2 or 3 degrees. This offset is also called camber, and it complicates the construction of the axle ends to such an extent that they must be machined with this slight angle either in the knuckle or in the axle, or distributed over the two places.

Fig. 362 shows the effect of this camber upon the front appearance of the car, the slight angle of the front wheels giving the car a bow-legged appearance.

Gather Further Complicates Axles. What the carriage men term "gather" further complicates the axle ends. This is the practice of setting the axle so that the front wheels are closer together at the front than at the rear, that is, they toe in. The idea of this is to make steering easier and, more particularly, to make the car self-steering on plain, level, straight-ahead roads. It is scarcely noticeable from in front, but is from above. Although many cars still have it, it is not used as much now as formerly.

MATERIALS

The materials utilized for front axles include castings of steel, manganese bronze, iron, and other metals, in the form of forgings, drop forgings, drawn or rolled shapes, and pressed shapes. Wood has been but little used and only in the past.

Cast Axles. Castings for front axles have been looked upon with grave doubt and fear by designers and owners, because of the fact that road shocks are more severe for front than for rear axles, and because of the fear that a casting may have a blowhole or some other defect. In addition to the natural distrust of castings for this work, it was feared that such material would crystallize more quickly than would a better and more homogeneous material like steel. There is, of course, a certain amount of crystallization in all materials, but far less in a close-grained fine-fibered structure like forged or rolled steel than in any form of casting. Aside from this, castings present many other advantages which are well worth while. Thus, the spring pads may be cast integral with the axle with practically no extra charge, while the same forged integral with a drop-forged axle may easily add several hundred dollars to the cost of the dies. Again, with casting patterns, the fillets may be changed easily to give a greater section here or to reduce a section there, while a similar action with any forged axle means a new set of dies, costing perhaps $600. There are many other machining helps which may be provided in cast axles without any extra cost.

Notwithstanding these many advantages, the casting for the front axle has been and is distrusted, and the makers who have used it have flown in the face of popular prejudice, for the public has mistrusted it even more than the makers. For this reason, the casting has been little used, and the writer fails to recall a single car with a cast axle now on the market.

Forgings. Forgings, as distinguished from drop forgings, are much used for good front axles, but are expensive. The writer knows of one excellent truck builder, striving to build the best truck in the world, who is using a hand-forged front axle, the end of which is shown in Fig. 359. It is forged down from a 6-inch bar of selected steel and the ends worked out so as to leave the bed proper a 2½- by 2½-inch section, which later has been increased to 3 inches square. This made a very costly piece of work, but the stand-up qualities shown in actual work more than made up for it as long as people could be found to pay the price demanded for a truck made along these lines.

Many smaller makers follow out the same scheme, the lighter work allowing the axles to be forged up much more quickly, more easily, and more cheaply. The smaller the amount of material to be heated, the less difficult will be the work, and the more quickly will progress be made. The general trend of axle practice today, however, is to turn over the axle job to specialists in that line, most of whom employ drop forgings, drawn- or rolled-steel tubing with drop-forged ends, or similar rapid-production forms of construction.

Drop Forgings. Drop forgings are now more used than any other form, although the first cost is great, for the dies must be very carefully worked out in a very high grade of steel; the result is a large expense of possibly $600 to $750 before a single axle is turned out.

As a matter of fact, with drop forgings, after the die is once made, the axles may be turned out rapidly, accurately, and with little labor and cost. Given the dies, therefore, there is no doubt that this method produces an axle at a very low first cost. Moreover, the method itself produces better quality, for any process which works steel or wrought iron over and over again improves its quality, provided the steel is not burned in the process of heating. Not only are the majority of axles made of drop forgings, but of those not so made some part is almost sure to be a drop forging, as, for example, those made of steel tubing which have their ends or other parts made by the drop-forging process. In Fig. 363 is shown a drop-forged axle used on a truck.

Tubular Axles. The I-beam section of front axle is universally used, and while the tubular type formerly enjoyed some popularity, its use today is confined to a very few vehicles. When employed, its ends are drop forged or drawn, or rolled steel may be used with the ends welded or otherwise secured. The disadvantage of the tubular type is the fastening of the ends which is more or less offset by the lowered cost of material.

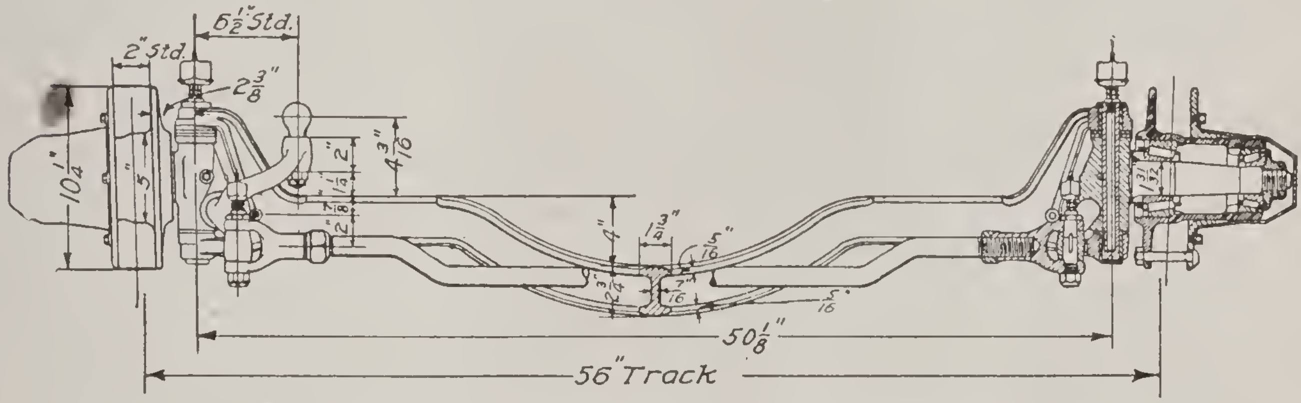


Fig. 363. Typical Drop-Forged Axle Used on Truck

Drop-Forged Ends. Nearly all the ends for axles made in this way are drop forgings, very few castings being used, while the spring pads, or spring seats, as they are sometimes called, are split into upper and lower halves and bolted on.

The loading conditions of all front axles are such that the load rests on the axle at two points inside of the supporting points—the wheels. Thus, the continual tendency of the load acting downward and of road shocks acting upward is to bend the center of the axle still further downward. Since a tube which has been bent once has been weakened, it follows that this tendency to weaken it presents a further source of trouble.

Pressed-Steel Axles. The pressed-steel type of axle, which made its initial appearance in 1909, and is not generally employed, consisted of a pair of pressed-steel channel shapes—one being slightly larger than the other—set together with the flanges inward so as to present a box-like shape. When thus arranged, the two sections were riveted together by a series of rivets running vertically along the center part of the channels. The ends consist of drop forgings, machined to size or space between the channels when assembled, and then set into place between the ends and riveted. The pressed-steel construction obtained a secure attachment to the bed. This axle was of the Elliott reversed type.

Change of Axle Type Simplifies. Often the change from one type of axle to the other is not made because the latter is better but because of some incidental saving in the manufacture. Thus, in Fig. 364, we see the reversed Elliott type at the left at *A* and the Elliott type at the right at *B*. From a manufacturing point of view, the former is much cheaper to construct, for the axle and knuckle costs would just balance one another, but the forging and machining of the one-piece steering arm shown in *B* would be more than double that shown in *A*. Moreover, the number of dies and their cost would be about three times as much, while the customer would have to be charged two or three times as much for repair parts. That is, in a modern low-priced car, produced in tremendous quantities, the advantages and costs connected with the two-piece steering arm of *A* would influence the choice of that design, regardless of other advantages or disadvantages.

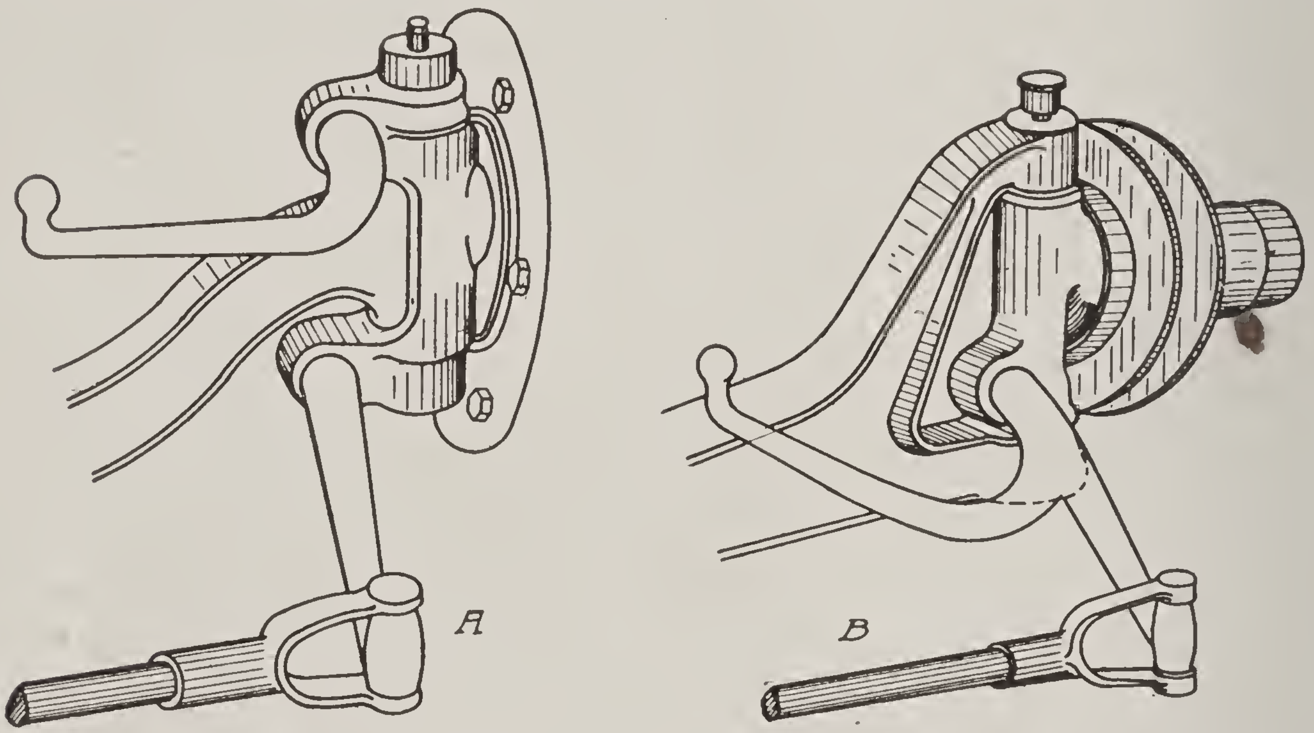


Fig. 364. Differences in Construction of Reversed Elliott and Elliott Types of Axle Knuckle

AXLE BEARINGS

Classification. Thus far nothing specific has been said about axle bearings. These are, according to construction, of three kinds: plain, roller, and ball. From the standpoint of the duty which they are to perform, bearings may be divided into radial-load and thrust bearings, all three forms mentioned above being used for both purposes, but arranged differently on account of the difference in the work. Each one of the three classes may be further subdivided. Thus, plain bearings may be of bearing metal or of hardened steel, or they may even be so constructed as to be self-lubricating. Again, plain bearings may mean no bearings at all as in the old carriage days when the axle passed through a hole in the hubs, and whatever wear occurred was distributed over the inside of the hubs, resulting after a time in the necessity for either a new set of hubs or a new axle, or for the resetting of the axle, so that the hubs set further up on a taper. Roller bearings may be of several classes, some makers using both straight and tapered rollers. In addition to these there are combinations of the straight and tapered types, and bearings with two sets of tapered rollers acting back to back, the action being that of straight rollers, with the end-adjustment feature of the tapered type. There are also many types of ball bearings, as, for example, plain ball bearings—those working in flat races, those working in curved races, those working in V-grooved races, and single balls working alone. There are also combinations of balls in double rows.

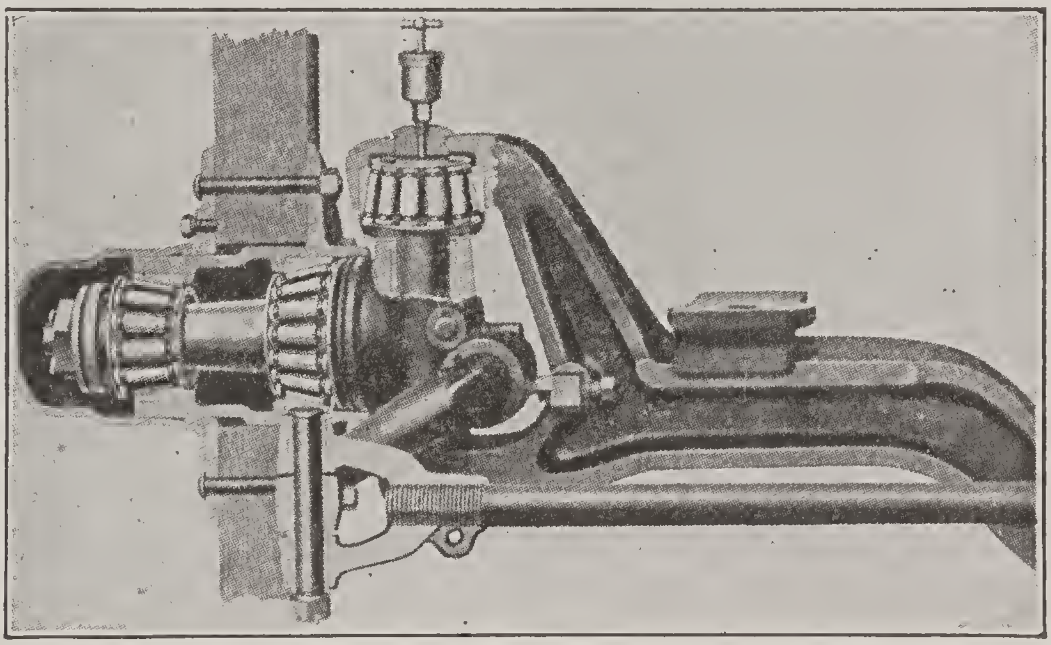


Fig. 365. Front Axle End, Showing Roller Bearings for Wheel and Steering Knuckle

Roller Bearings. Fig. 359 shows the use of tapered roller bearings for the hubs and of hardened-steel thrust washers for the thrust load, the figure showing, in addition, a plain brass bushing in the axle for the knuckle pin to turn in. In Fig. 365 is shown a more elaborate use of roller bearings of very excellent design. In addition to the axle bearing, it will be noted that the top bearing of the steering knuckle is of the roller type.

Ball Bearings. Although there is a growing tendency to utilize a short adjustable type of roller bearing, many designers favor the ball bearing. The two most common forms are the cup and cone type, which cares for radial and thrust loads, and the annular form which is suited for supporting annular loads. The annular form is not adjustable, and when it wears it must be replaced with a new bearing. The cup and cone type is adopted by makers of low-priced and medium-priced cars, has an angular contact, and is adjustable.

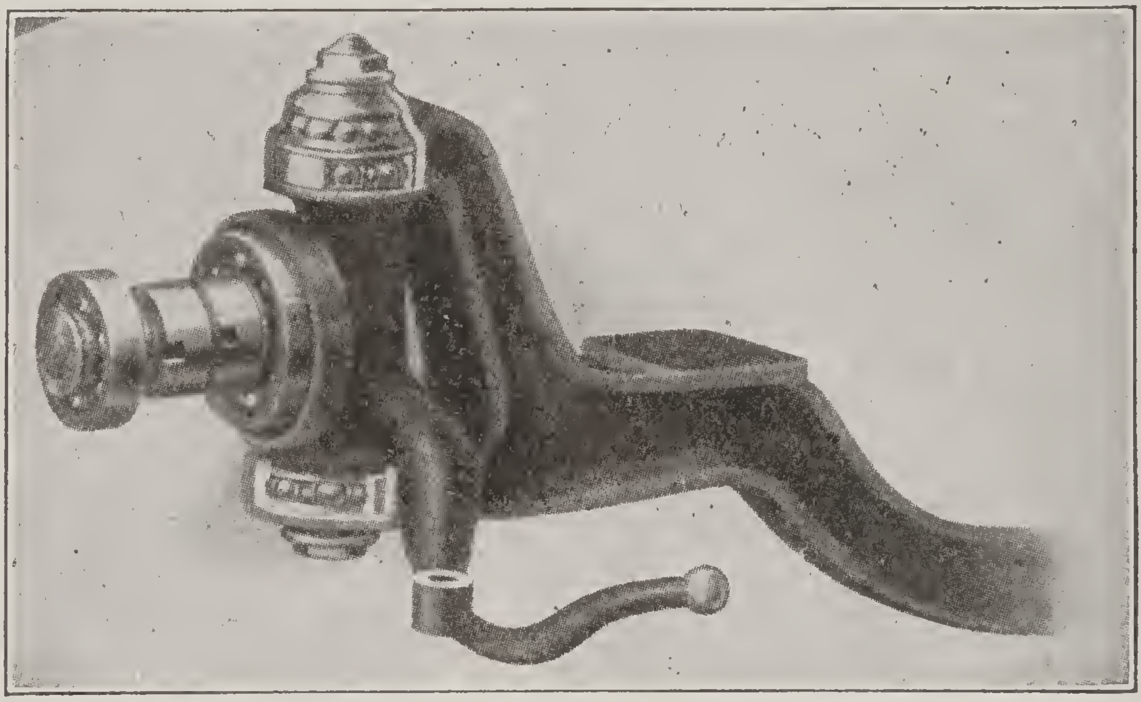


Fig. 366. Front Axle and Steering Knuckle of Superior Construction

In some instances, particularly with high-grade cars, ball bearings are used for the knuckle bearings as well as for the hub. Fig. 366 is an example of an axle end, which for real bearing worth, has probably never been surpassed; this is the axle end and steering knuckle of a very high-priced car, not now made, but one on which no expense was spared to make it perfect. The illustration shows the wheel hubs running on two very large diameter ball bearings, while the knuckle also turns on two very large ball bearings arranged for radial loads. At the top is another ball bearing arranged for thrust; this bearing taking up all thrust loads from the weight above or from road inequalities. Fig. 367 illustrates the cup and cone type, This design utilizes ball bearings for the hubs and plain steel thrust washers on the knuckle.

FRONT AXLE TROUBLES AND REPAIRS

Alignment of Front Wheels Troublesome. The lack of alignment of front wheels gives as much trouble as anything else in the front unit. This lack not only makes steering difficult, inaccurate and uncertain, but it also influences tire wear to a tremendous extent. As Fig. 368 indicates, even if the rear axle should be true with the frame, at right angles to the driving shaft, and correctly placed crosswise—correct in every particular with the shafts both straight so that the wheels must run true—the fronts may be out with respect to the frame, out of track with the rears, or out with respect to each other.

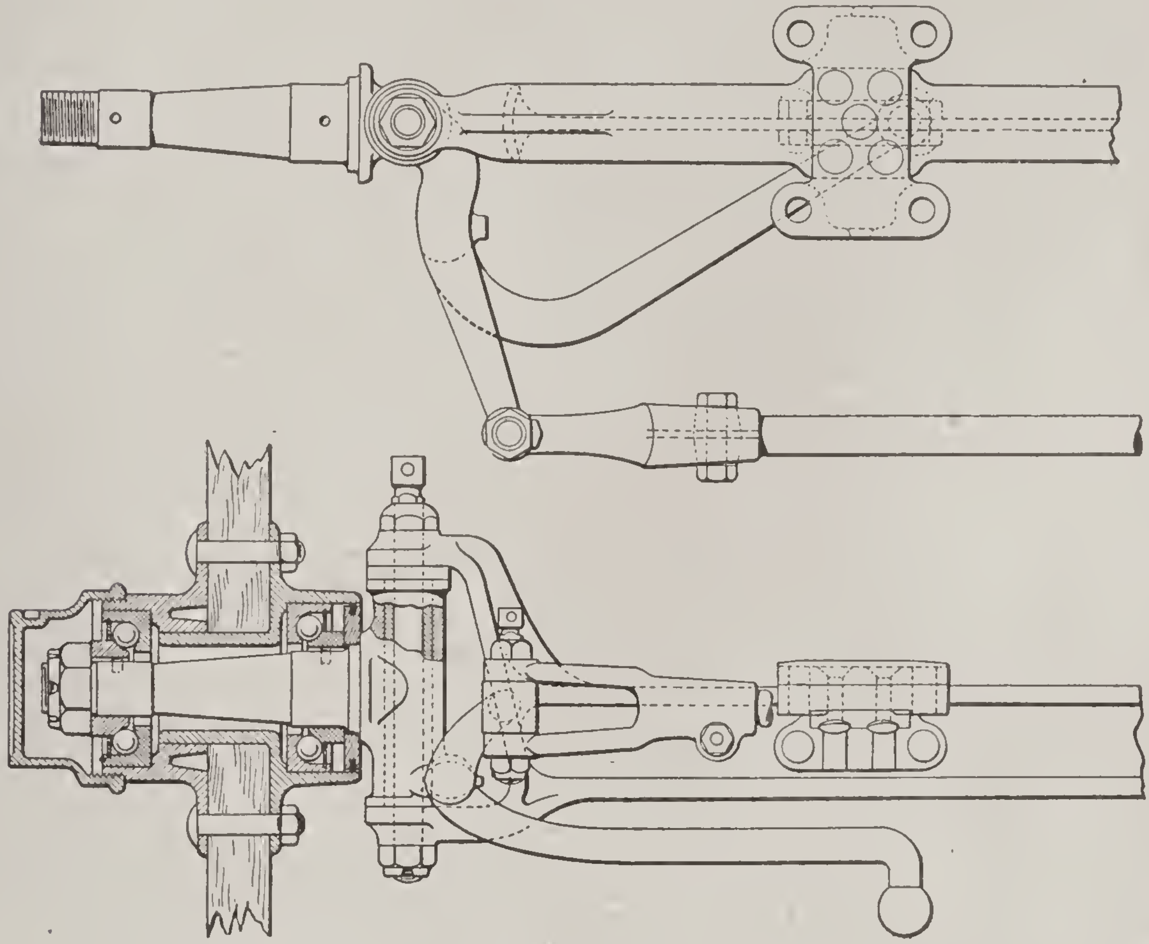


Fig. 367. Front Axle Details of Waverley Electric Car
Courtesy of the Waverley Company, Indianapolis, Indiana

In order to know about the front wheels, they should be measured; while this sounds simple, it is anything but that. In the first place there is little to measure from or with. A good starting place is the tires, and a simple measuring instrument is the one shown in Fig. 369. This instrument consists of a rod about $\frac{1}{4}$ inch in diameter and about 3 feet long, fitted into a piece of pipe about 2 feet long, with a square outer end on each, and a set screw to hold the measurements as obtained. By placing this rod between the opposite sides of the front tires, it can be ascertained whether these are parallel, and whether they converge or diverge toward the front. But knowing this, the driver or repair man is little better off than before, because this may or may not be the practice of the makers of the car, and it may or may not cause the trouble.

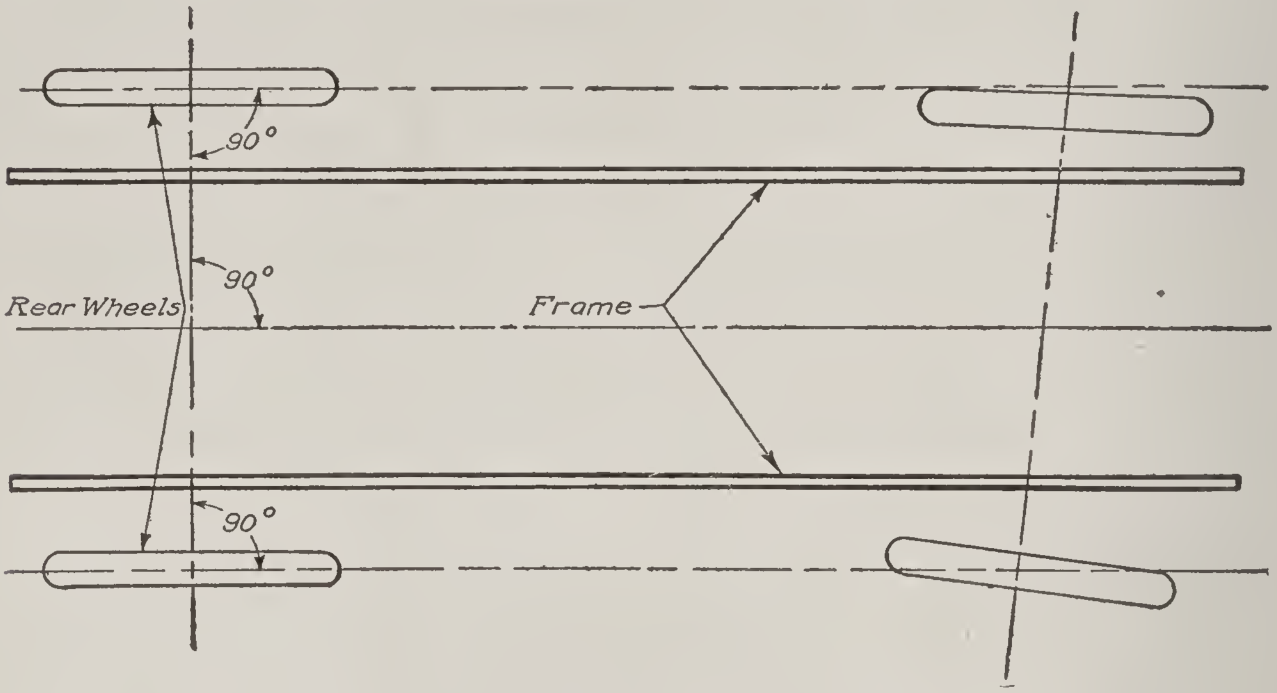


Fig. 368. Diagram Showing Front Axle and Wheels Out of True

In short, a more accurate and more thorough measuring instrument is needed, Fig. 370. Such an instrument can be bought, but a similar outfit can be made from $\frac{3}{8}$-inch bar stock, using thumb nuts where the two uprights join the base part, and also at the two points, or scribers, on these uprights. Having the floor to work from, the heights can be measured, and thus the distance between tires may be taken on equal levels. Thus, a bent steering knuckle can be detected with this apparatus. Similarly, the center line and frame lines of the car can be projected to the floor, and by means of the instrument, it can be determined whether the axle is at a perfect right angle

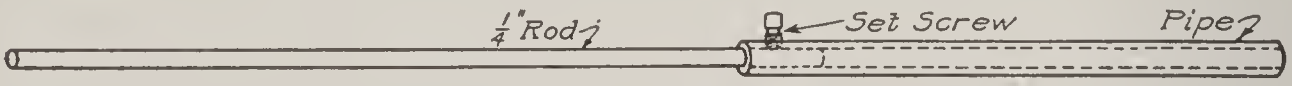


Fig. 369. Simple Measuring Rod for Truing-Up Wheels

with the frame lines, and whether the wheels are perfectly parallel. Given the frame line, too, it can be determined whether the wheels track with one another.

Straightening an Axle. When an axle is bent, as in a collision, a template is useful in straightening it. This can be cut from a thin sheet of metal, light board, or heavy cardboard. It is an approximation at best and should be used with great care. Fig. 371 shows such a template applied to an axle which needs straightening.

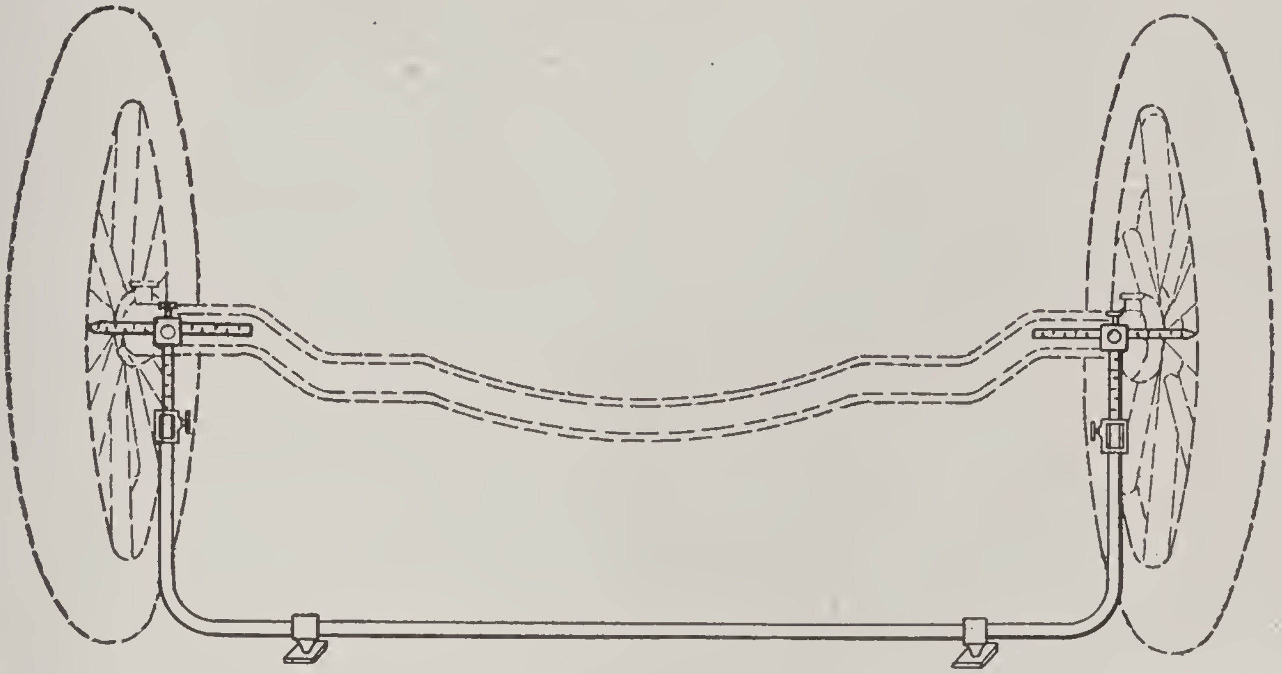


Fig. 370. Accurate Measuring Rod for Truing-Up Wheels. Better Design than Fig. 369

When the axle is bent back to its original position, a pair of straightedges laid on top of the spring pads will be of great assistance in getting the springs parallel, as the worker can look across the straightedges with considerable accuracy. This is indicated in the first part of Fig. 372, which shows the general scheme. It shows also how the axle ends are aligned, using a large square on top of a parallel bar, but of course this cannot be done until the last thing, at least not until the spring pads are made parallel.

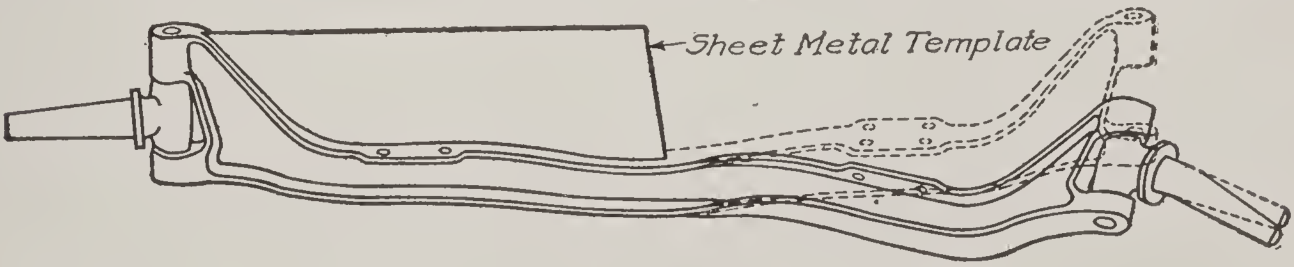


Fig. 371. Template for Showing if Axle Is Bent

Front axles of light cars may be straightened without removal, provided the bend is not in the nature of a twist and not too short. Take two hardwood planks 7 feet long, 10 inches wide, and 2 inches thick. Next, cut four ¾-inch blocks 10 inches long and 3 inches wide. Lay the blocks flat between the planks, space them about 2 feet apart, and bolt the whole securely. This obtains a girder 7 feet long, 10 inches wide, and 4¾ inches thick. Next, take two pieces of 4×4 timber 3 feet long and cut a tenon on one end of each. Make three ¾-inch eye bolts, 12 inches long, with nuts and plate washers for each. Place one of the eye bolts between each pair of blocks and screw up the nuts and washers sufficiently so as to rivet them. This permits of moving the eye bolts to any position between the blocks. Two small steamboat ratchets and several short but strong chains complete the equipment.

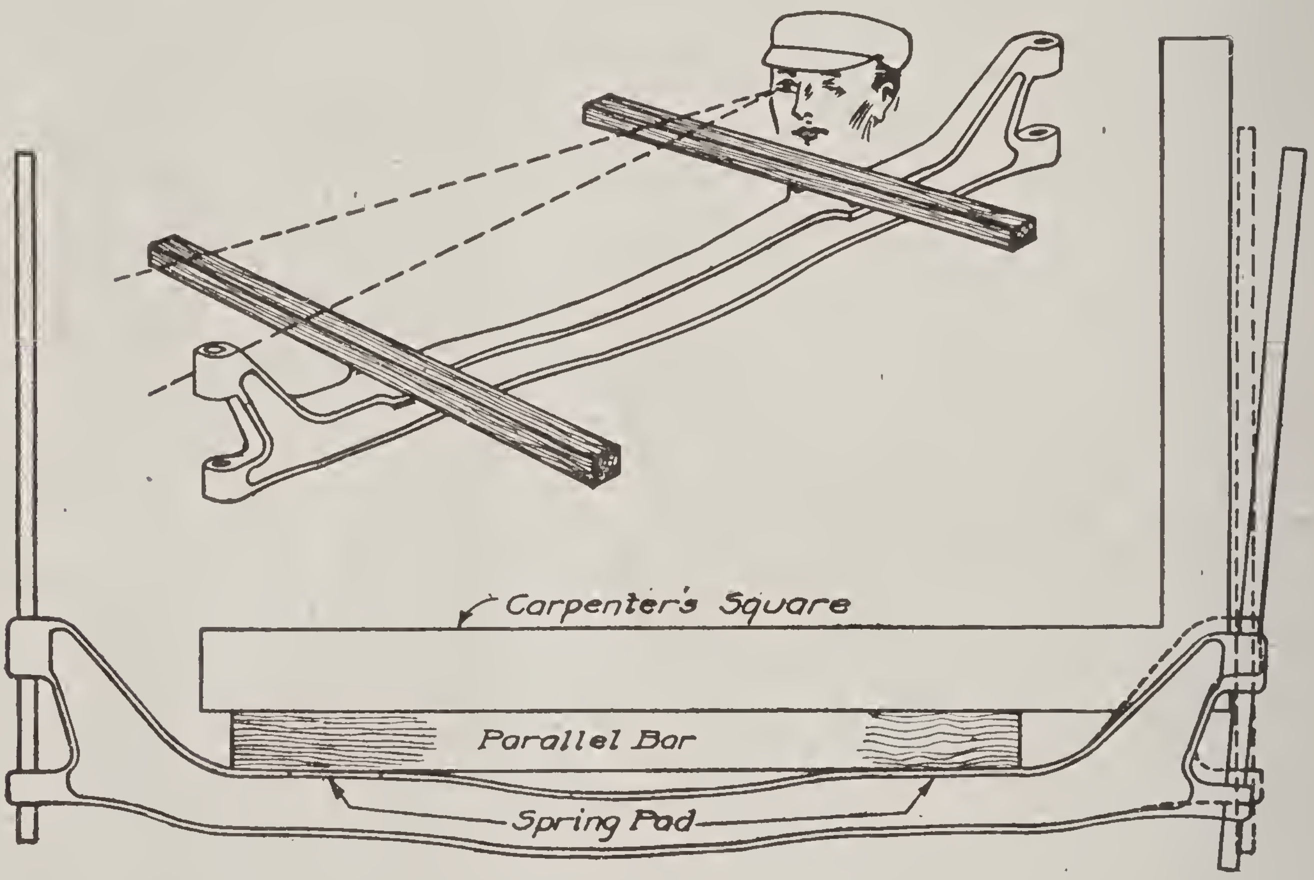


Fig. 372. Diagram Illustrating Method of Truing-Up an Axle

With an axle bent back in the center, lay the girder on blocks in front of the car so it will be level with the axle, place the tenons of the 4×4 timbers in the space between the planks of the girder, one on either side of the bend, and connect the axle to the girder by means of a chain, the ratchet, and the eye bolt. When the ratchet is tightened up, it draws the ends of the 4×4's against the axle on either side of the bend. Tightening the ratchet still further removes the bend. This work may be accomplished in 20 minutes or less or in about one-tenth the time it will require to displace the axle, heat it, and straighten on an anvil, etc. The apparatus can be used for straightening many different bends; all that is necessary is a different arrangement of its parts.

For example, a downward bend can be straightened by placing the car above the girder, connecting the axle to the girder, and using a short screw jack to remove the bend. This device can be used with success in shops dealing with light- or medium-weight cars.

Spindle Troubles and Repairs. Wear of the spindle, or knuckle bolt, and its bushings, as well as play in the steering-gear linkage, brings about wobbling of the front wheels when the car is in motion. Some experienced persons mistake wear of the knuckle and the bushings for play in the wheel bearings, and attempt to remedy the trouble by adjusting the bearings. It is a simple matter to determine the component at fault. To test for bearing play, drive a block of wood between the knuckle and the axle, then grasp the wheel at the top and bottom, or at points diametrically opposite, and test for looseness. If none exists, the play is in the knuckle pin and its bushings. The remedy is to fit new bushings and new knuckle pins.

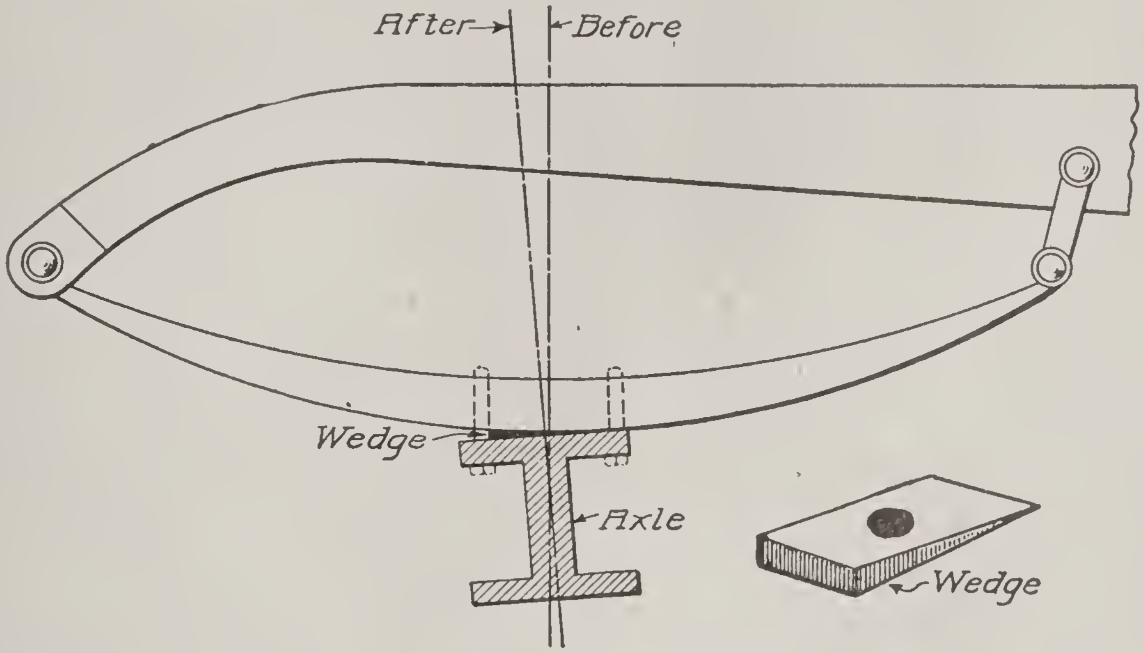


Fig. 373. Use of Wedge to Cure a Wobbling Wheel

Wobbling Wheels. Wobbling of the front road wheels is generally due to play in the joints of the steering mechanism, and it is not only troublesome, but also sets up undesirable stresses on the steering-gear linkage. This flapping of the wheels may be present with the steering gear and linkage in perfect operating condition, and similarly when the springs, hangers, etc., are in good condition and the proper toe in, or gather, of the wheels exist.

When the wheels wobble it may be assumed that the front springs have so settled that the steering pivots are not quite vertical fore and aft, particularly with reference to that type of pivots which do not incline outwards and where the wheels are canted or dished to bring their points of ground contact in line with the pivots. A cure for this trouble is to place wedges between the front springs and spring seats so as to alter the angle of the steering pivots, as shown in Fig. 373. Metal wedges are used, about $\frac{1}{8}$ inch thick at the large end, and tapered to a knife-like edge. The wedge is placed at the forward end of the axle, and a little experimentation will give the results desired. In wedging, as few wedges should be used as is necessary to obtain the desired result.

CHASSIS GROUP

In arranging a logical presentation of the numerous components of the motor vehicle, the chassis is separated from the body. It includes the power plant and mechanism utilized in transmitting the energy of the engine to the road wheels, also the frame and suspension, the axles, etc. However, only frames, springs, and shock absorbers will be discussed in this section, as the other parts of the chassis have been treated.

Characteristics of Parts. *Frames.* The chassis frame practically is the foundation of a motor vehicle, since all of the power transmitting and other units are attached to it. Motor-vehicle construction depends, to a certain extent, upon the general design of the chassis, the construction of the power plant and transmitting units, their mounting, the method of final drive, the wheelbase, etc. The size of the material used depends upon the weight of the units carried and the capacity of the vehicle, and varies from thin and small sizes on very light pleasure cars to heavy structural I-beam frames on commercial vehicles.

The use of pressed steel is becoming more popular, as is also the tendency to narrow the frame at the front to obtain a shorter turning radius. The majority of designers favor what is termed a kick-up at the rear, which affords better spring action and permits of a low suspension of the body. The use of tubing and wood has practically been abandoned. There is a slight return to favor of the underslung suspension, a form that was popular several years ago but which did not then obtain the results claimed for it, as the springing gave some trouble.

Springs. The primary function of the spring is to absorb the road shocks that would otherwise be communicated to the mechanism and passengers. Considerable progress has been made in the past year toward improving springs, and not only are they better proportioned, but improved material and methods of mounting have, to a great extent, eliminated breakage. The leaf type, developed by the horse-drawn carriage industry, is the form universally employed on motor vehicles, both pleasure and commercial.

A review of the 1916 springs for cars showed that the three-quarter and seven-eighths elliptic spring was favored by 46.5 per cent of the makers, while some form of cantilever spring was second with 28.7 per cent for rear suspension. This year the advocates of the cantilever have gained many new recruits. In the matter of front springs, the semi-elliptic may be said to practically monopolize the field. The coil spring is a thing of the past.

Shock Absorbers. The fitting of shock absorbers as standard equipment is not as noticeable as it was in 1916 and the year previous. The use of high-speed engines with light reciprocating parts, and the employment of high-grade light material in other components of the chassis, together with better springs, serves to absorb shocks created by traversing rough roads. A few makers supply shock absorbers, but, as a rule, the car manufacturer leaves the selection to the purchaser. Many different types of shock absorbers are marketed, and use is made of varying principles.

FRAMES

General Characteristics. When the automobile was first introduced, comparatively little attention was paid to the frame, as the other components of the chassis, such as the power plant, gearset, axles, etc., were held to be of greater importance, consequently the frame did not receive the consideration it should. After experiencing considerable difficulty, however, due to accidents and other failures which were traced directly to poor frame design, the automobile engineer found that it was possible to build a frame of great strength with less weight than the troublesome types. This statement applies to the frame of the commercial car as well.

The improvement in frame design is the result of the tendency to provide perfect alignment of the power plant, clutch, and gearset, making use of what is known as the unit power plant on some models, while on others, particularly of the heavier type, flexible mounting of the units has been resorted to. The tendency is toward the use of a flexible mounting of all individual units, at least to some degree, in order to relieve them of the stresses brought about by frame weaving when the road wheels mount an obstacle on the road surface.

Classes of Frames. The most prominent types of frames, divided according to their use, are the pressed-steel frame, the structural frame, and the structural **I**-beam frame; the latter is confined to commercial cars. These classes may be subdivided according to the general construction and material, as well as to the distribution of the chassis units.

The material employed is either pressed or rolled steel. The wood frame or combinations of wood and metal frames are practically a thing of the past, and are to be found, with one or two exceptions, on old cars. The steel frame may be constructed in the following shapes: channel, **L**-beam, angle, **T**, **Z**, tubing, flat plates, and combinations of any two or more of these. Other forms are possible. For example, the channel may be turned with the open side in or out, the two constructions being widely different; or the angle may have the corner down and out, down and in, up and out, or up and in. Similarly, the **T**-shape may be a solid **T** turned up or down, or it may be a hollow **T**-section with space between what might be called the two sides of the leg; this shape may be turned either up or down, while the **Z**-shape may be turned horizontally or vertically. Many frames are constructed with the open end of the channel section turned in, and use is made of a steel underpan of flat section attached to the under side of the main frame. In several instances there is a tendency to make the frame and underpan as one piece, in which case the frame section assumes the shape of a channel with an exceedingly long lower flange.

Another type of frame is that having a continuous section throughout. Others have a varying section. Thus, the ordinary steel frame of modified channel section may have a depth of perhaps 5 inches at the center, a width of upper flange of $1\frac{1}{4}$ inches, and a width of lower flange of 2 inches. A frame similar to this would taper down to the ends to perhaps 20 inches in vertical height, and to 1 inch in width of both top and bottom flanges. Then, again, frames which are bent upward or downward at the ends or in the middle really differ from those frames which preserve one level from end to end. The practice of bending the chassis frame is very prevalent of late, the upturning of the ends bringing about a lower center of gravity, making for stability and ease of entrance and exit to the body.

Tendency in Design. There is a marked tendency toward making the chassis frame wider at the rear and narrower at the front. In one or two cases the designer appears to have gone to the extreme in this respect. The advantage of the narrow front construction is that it enables the car to be turned in a shorter radius. The use of a wide rear frame provides more space to support a wider body. A more recent development is to make the longitudinal bars of the frame parallel over the front spring and near the rear spring, and to have them tapered from behind the front to the rear springs. A certain amount of material is said to be gained by this construction, as no heavy reinforcement or sudden offset is necessary to the frame. By widening the frame at the rear it makes possible the placing of the springs directly underneath the frame. Some car makers have the sides of the frame straight over the entire length, but tapered from the front to the rear.

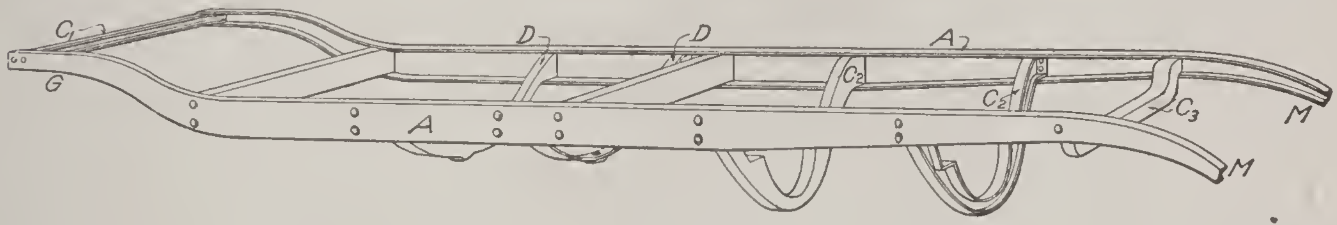


Fig. 374. Typical Automobile Frame of Pressed Steel

Fig. 374 illustrates what is termed a single drop or a kick-up. This is a type of pressed-steel construction, of channel section, and the deepest and strongest section is at the center where the greatest stresses occur. Some frames are built with a double drop, having a downward bend just forward of the entrance to the rear part of the car body, followed by an upward turn just back of the same entrance. The upward turn at the back is carried higher than the main part of the frame for the purpose of obtaining a low center of gravity. Then there is what is termed the bottle-neck construction, a bend inward which resembles that in the neck of a bottle. This obtains a short turning radius. Originally, frames were narrowed in front, the difference in the width between the front and rear being at first an inch or so on each side, gradually increasing until it became 5 and 6 inches. This type did not prove efficient, and the trend favored the taper previously explained.

A not uncommon form of frame is shown in Fig. 375, which compensates for an abnormal rise of the rear axle without the possibility of its striking the frame. Some frames have a bend at the ends to take the spring fastenings.

Pressed=Steel Frames. The pressed-steel type of frame is very popular with designers and is largely used on commercial cars up to and including 1-ton capacity. This is popular because it is the lightest in weight for equal strength of the structural iron or rolled channel and I-beam section. The cost of pressed steel is somewhat higher, because it is heat-treated material used to obtain maximum strength. The cost varies with the section, material, and the nature and extent of bending. The finished frames are easy to handle, and the assembling cost is small. The channel shape is easy to brace and repair. These and other advantages have brought about its use.

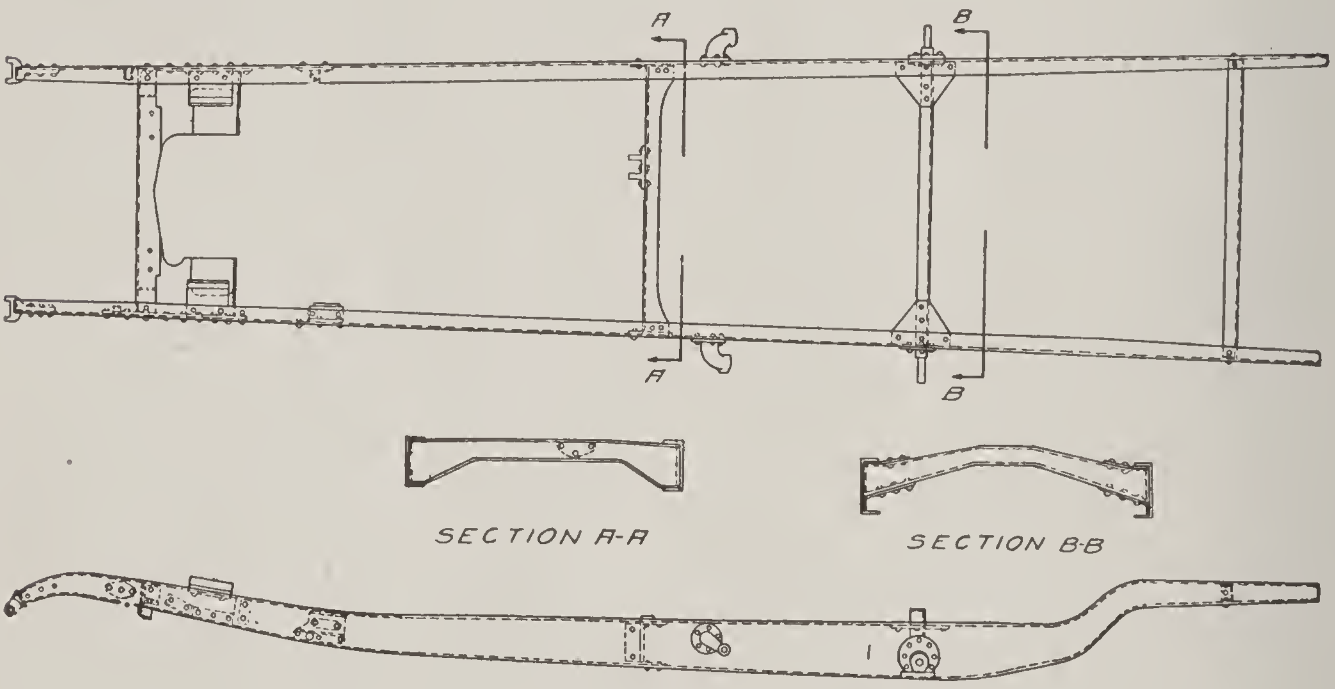


Fig. 375. Frame of Sterns-Knight Car in Plan

The cheapest construction is the straight side rail, and, when conditions permit, it is usually tapered at front and the rear, and the forward end is sometimes shaped to receive the spring hangers. When the side members are inswept to permit a short turning radius, it is necessary to make the flanges of the side rail of considerable width at this point, tapering gradually to the rear, to provide the proper strength at the point of offset.

Sub-Frames. The modern tendency is to eliminate the sub-frame—a step due to the flexible mounting of the power plant and unit construction—because it simplifies the frame. It has also been made easier by the tapered frame, which is narrowest at the front where the units are attached. The most common method of supporting the engine is the three-point. Sub-frames are used, however, as they serve the purpose both of supporting some unit and of strengthening the frame.

Sub-frames may be of two kinds, viz, those in which the sub-frame is made different for each unit to be supported, and others in which one sub-frame supports all units regardless of size, shape, or character of work. The type of sub-frame made to support each unit usually works out to two pairs of cross-members, one for the front of the unit and one for the rear; while the type which supports all units regardless of size works out to longitudinal members, supported, in turn, by two cross-members, front and rear. The added weight for the first-mentioned type is less than for the other, since it comprises only four cross-members; while the last-named type consists of two cross-members equal to two of the others and of two very long members parallel to the main-frame members, each much longer and thus much heavier than the corresponding cross-members. In the two frames already shown, Fig. 374 shows the unit type of sub-frame with only cross-members, while Fig. 375 shows the more modern type in which the power plant is of the unit type and rests directly upon the main frame, being the three-point suspension type in which the forward point is on a frame or special cross-member, while the rear two points are the crankcase supporting arms resting directly on the main frame.

Rigid Frame. A pressed-steel or rolled-stock rigid frame has its advantages, particularly with reference to the commercial vehicle. It permits the body to be rigidly secured to it, and as it does not give with the inequalities of the road, the body is not racked. An advantage of the rolled stock is its cheapness, except, of course, for the lighter models of the assembled type for which frames can be secured at low figures. Another advantage of the rolled stock is the ease with which the wheel base may be altered.

Effect on Springs. The effect of frame construction upon the design and duty of springs should be considered. This feature

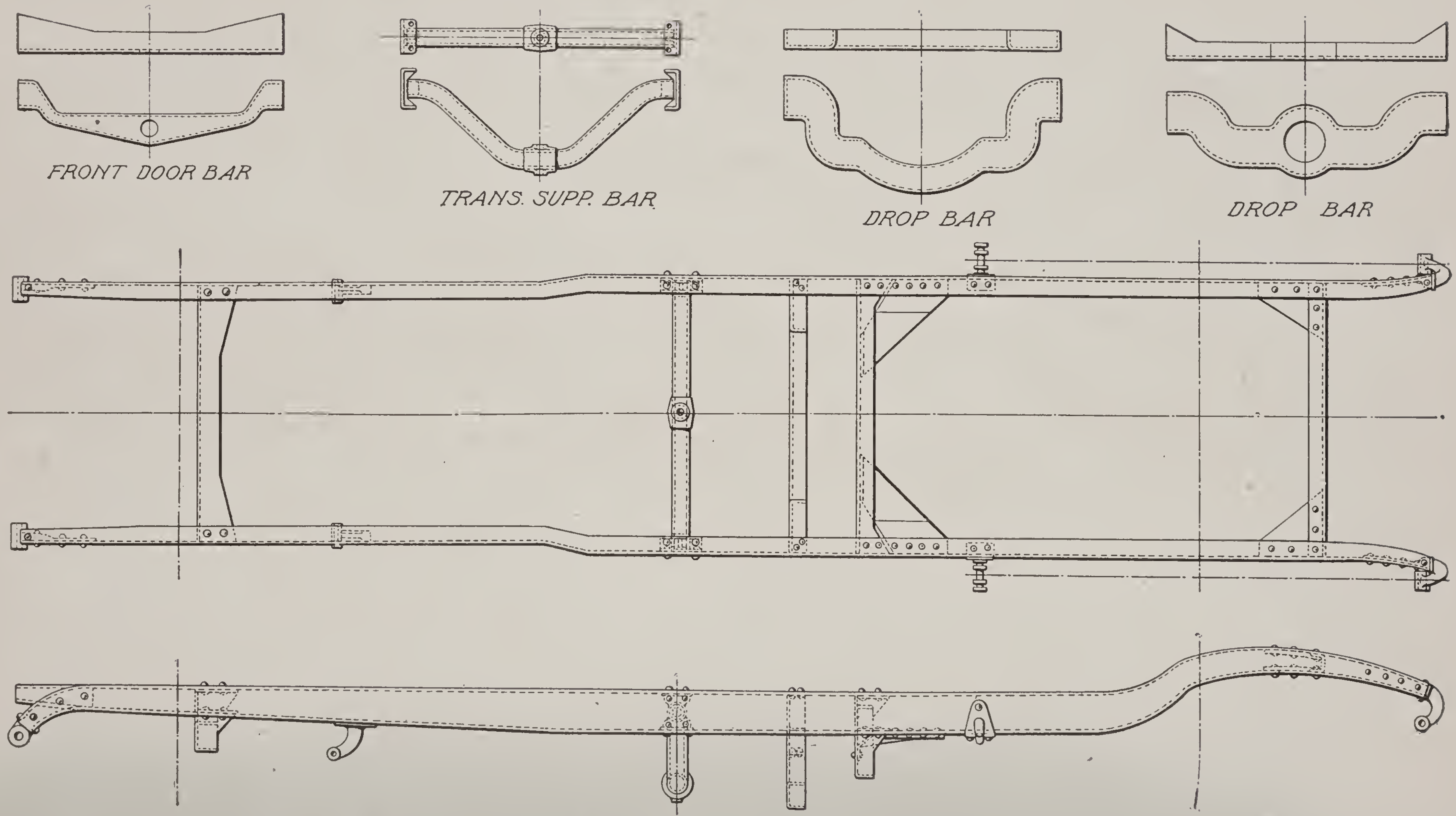


Fig. 376. Plan, Elevation, and Sectional Details for Chassis Frame with Narrowed Front
Courtesy of A. O. Smith Company, Milwaukee, Wisconsin

is not generally understood, but it has an important bearing upon the life of the car. A rigid frame relies upon the springs to allow for all axle displacement. If a front and a rear wheel on opposite sides are raised several inches at the same time, the frame is subjected to a torsional stress. If the frame is rigid, springs of considerable camber must be employed in order to absorb the shock without being bent past the limit of safety, and they must be sufficiently flexible to absorb all the shock without any tendency to lift the other wheels from the ground. To accomplish this shock absorption, a different type of spring is used on a rigid chassis from that employed on a flexible frame. The use of underslung spring suspension has come into favor for this reason, as it permits the frame to be carried fairly low, without sacrificing spring camber or necessitating a dropped rear axle.

The flexible frame, when diagonally opposed wheels are raised, does not impose all the stresses on the springs but it absorbs a part of them. For this reason, springs on a flexible chassis are flat or nearly so, with a limited amount of play. Flexible construction also permits the frame to be carried equally as low as with the underslung spring, and yet the spring is perched above the axle, where it is more nearly in line with the center of gravity, thus reducing side sway.

TYPES OF FRAMES

Pressed Steel. Pressed steel is purchased in sheet form, cut to the proper shape in the flat, and then pressed into channel form under great pressure. It is made of steel rolled into sheets and is somewhat closer grained than ordinary steel. There is no breaking of the flake in the rolling process. The pressed-steel frame, as previously pointed out, permits of greater simplicity in assembling, since the parts can be easily bolted or riveted. Fig. 376 is of the type of pressed-steel frame having a tapering section, a kick-up at the rear end, five cross-members —one of them a tube—and is narrowed in at the front to give the largest steering lock. Otherwise it presents only standard practice.

Wood. Wood is universal and easy to obtain. While no longer classed as cheap, it is not expensive; moreover, wood is kept in stock nearly everywhere. Users of wood for side-frame members claim that the wood frame is not only lighter but stronger. In addition, the wood frame would undoubtedly possess more natural spring and

TABLE IV

Comparative Strength of Steel Channels and Laminated Wood Frames

Material	Size (in.)	Weight per Linear Inch (lb.)	Resisting Moment	Resisting Moment per Unit Weight
Pressed Steel	$\frac{3}{16} \times 4\frac{1}{2} \times 1\frac{3}{4}$	.408	114,830	280,955
Ash	$1\frac{3}{4} \times 6$	.266	142,275	534,870

resiliency, so that it would make a lighter and easier riding frame. A section of a wood frame is shown in Fig. 377.

This shows a frame made of laminated wood. There are three very thin sections of selected ash, marked *A*, which are glued together, then screwed and bolted to prevent the glue from opening up. To further this purpose, a strip *B* is fastened on the top and bottom in the same manner. These strips are laid with the grain running horizontally, while the main pieces are laid with the grain running vertically. This construction makes a very strong and light-weight frame; the comparative figures for a steel section and the section shown, as given from the tests of the engineers of the Franklin Company, is shown in Table IV. These tests, which are authentic, seem to bear out the contention that the wood frame is both lighter and stronger than the steel frame.

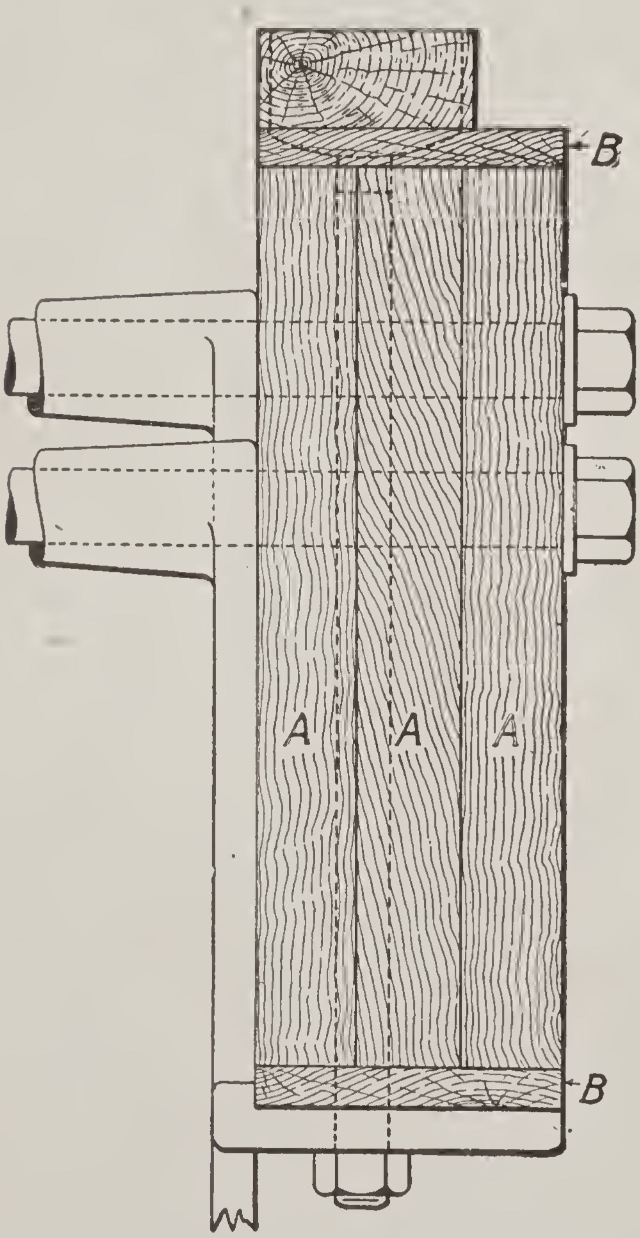


Fig. 377. Section through Wood Side-Frame of Franklin Car

Novelty of Fergus Frame. A new American car, the Fergus, shows more novelty in frame construction, as well as in every other conceivable way, than any other. Instead of blindly following accepted practice in the matter of frame design and construction, the makers have struck out boldly along new lines.

The Fergus car was developed as a result of fifteen years' experience in fine repair work, and is an attempt to eliminate the usual "owner troubles". While not intended as a "foolproof" car, the Fergus comes nearer being one than any other developed up to this time. In addition to actually "foolproofing" the car, the aim of the makers was to eliminate much of the work incident to caring for the modern car by replacing the usual "owner-attention" with an automatic system.

In the frame, a combination of steel girder and lattice work has been produced which has the appearance of being absurdly light. However, as the diagram of stresses in its members, Fig. 378, indicates, everything has been figured out with the utmost care, and the design has been supplemented by unusual workmanship.

The complete frame, Figs. 379 and 380, shows that a large part of the saving is produced by the method of suspending the units. Were these hung on the side members, as in the ordinary case, the frame certainly would not do, but as it is, they are hung on immensely strong brackets, steadied by the side members, but rigidly supported by large tubular cross-members. The brackets and cross-members do the work ordinarily assigned to the side members of the frame, the side members simply joining and holding together the various brackets and cross-members.

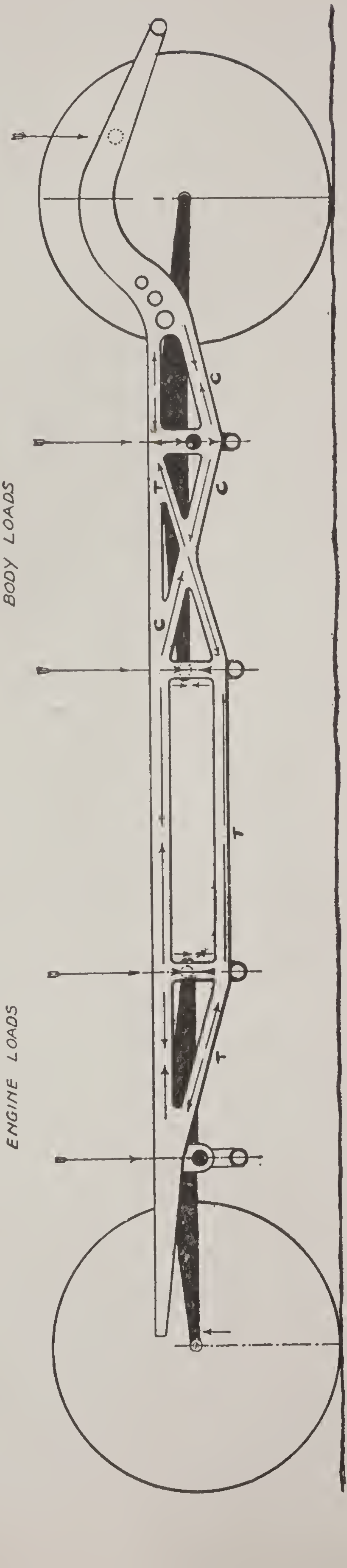


Fig. 378. Diagram of Fergus Trussed Frame, Showing Light but Strong Construction

An examination of the design reveals the astonishing extent to which the brackets have been combined, the rear engine member, for instance, also acts as the rear support for the front spring, for the step support, and for the dash support. At the sides and rear there is a similar combination of functions.

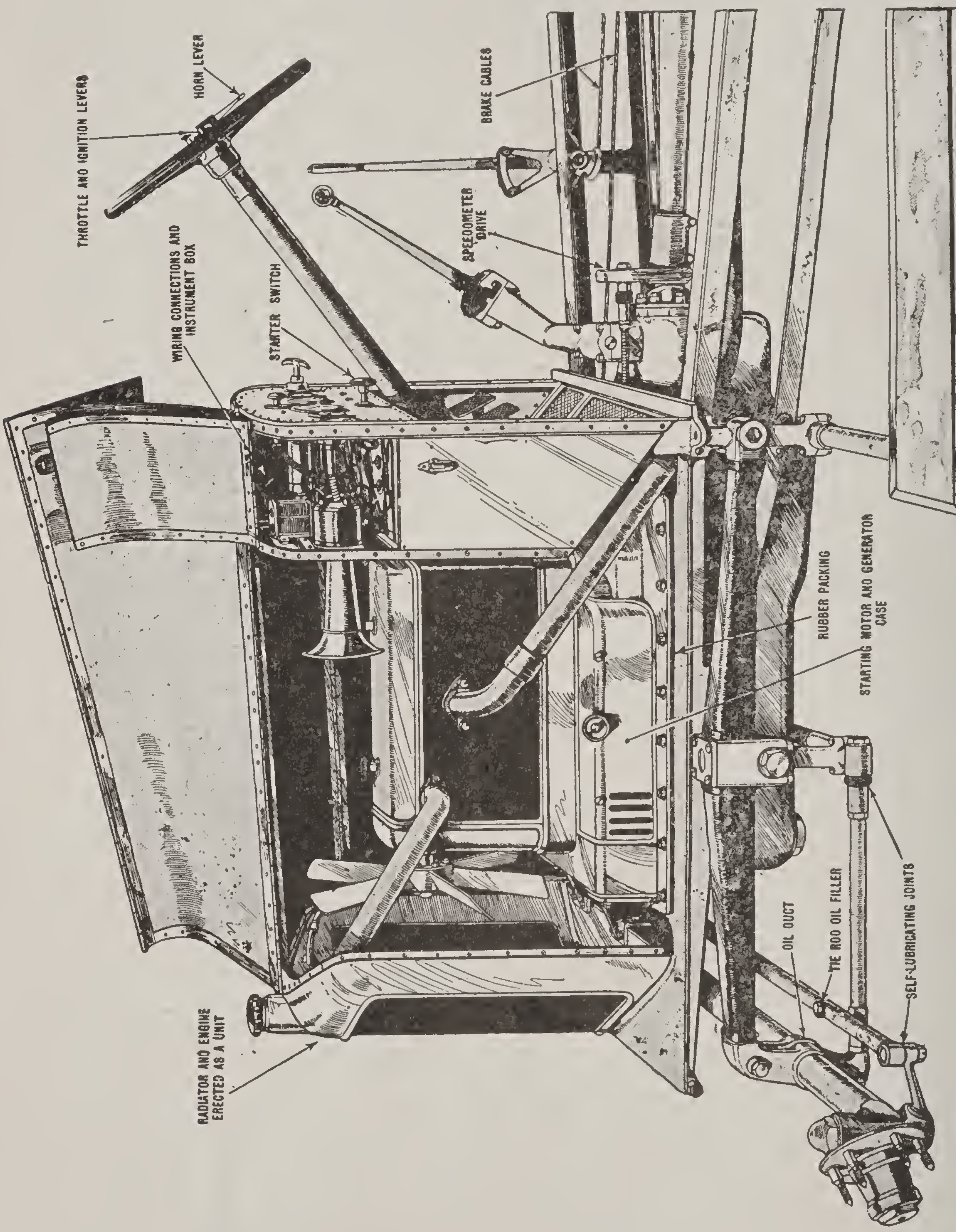

THROTTLE AND IGNITION LEVERS
HORN LEVER
BRAKE CABLES
WIRING CONNECTIONS AND INSTRUMENT BOX
STARTER SWITCH
SPEEDOMETER DRIVE
RUBBER PACKING
STARTING MOTOR AND GENERATOR CASE
OIL DUCT
TIE ROD OIL FILLER
SELF-LUBRICATING JOINTS
RADIATOR AND ENGINE ERECTED AS A UNIT

Fig. 379. Forward Portion of Chassis of Fergus Car, Showing Method of Attaching Springs, Front Axle, and Engine

Recent Types of Frames. An innovation in frame design is the Marmon, shown in Fig. 381, the side rails and running boards of which are made in a single unit. The great width of the running board,

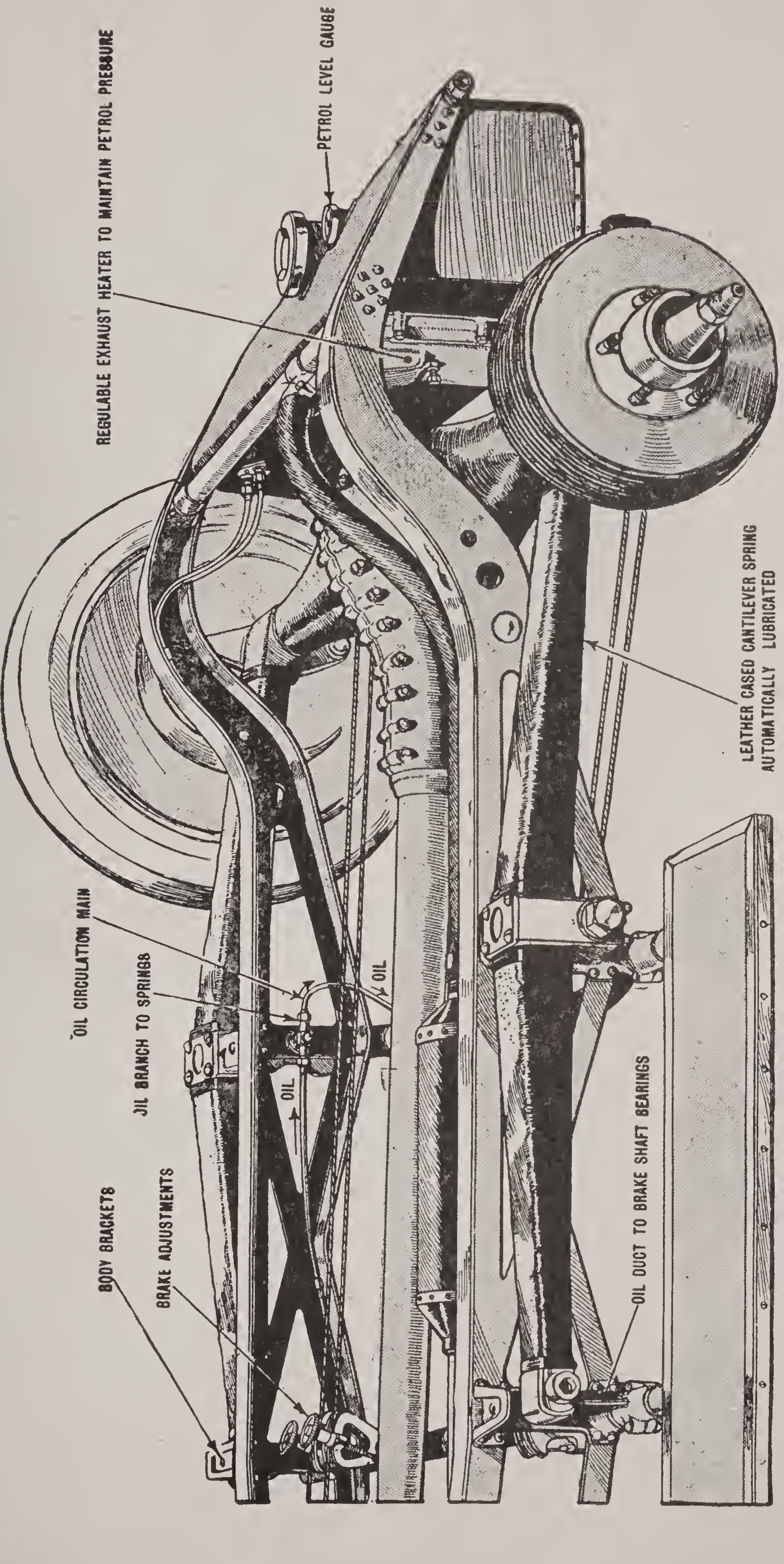

REGULABLE EXHAUST HEATER TO MAINTAIN PETROL PRESSURE
PETROL LEVEL GAUGE
LEATHER CASED CANTILEVER SPRING AUTOMATICALLY LUBRICATED
OIL CIRCULATION MAIN
OIL BRANCH TO SPRINGS
OIL
OIL
BODY BRACKETS
BRAKE ADJUSTMENTS
OIL DUCT TO BRAKE SHAFT BEARINGS

Fig. 380. Rear Portion of Chassis of Fergus Car, Showing Simple Spring and Rear-Axle Construction

varying from $11\frac{1}{2}$ to 16 inches, serves as the bottom flange of the frame, and is therefore of **Z**-section. The vertical section of the frame is 10 inches high, and has height enough to replace the running board fenders without appearing narrow. At the front and rear ends of the frame, the running boards are curved upward, strengthening the frame as well as supporting the fenders into which they merge. The frame, beyond these points, both forward and rearward, is made of channel section of the conventional type. The rear of the frame is 45 inches wide and tapers to 30 inches at the front spring hangers. The great depth of the frame section makes it very stiff, so that the body sills can be entirely eliminated, and yet the doors will not work loose or bind when the top is up or down.

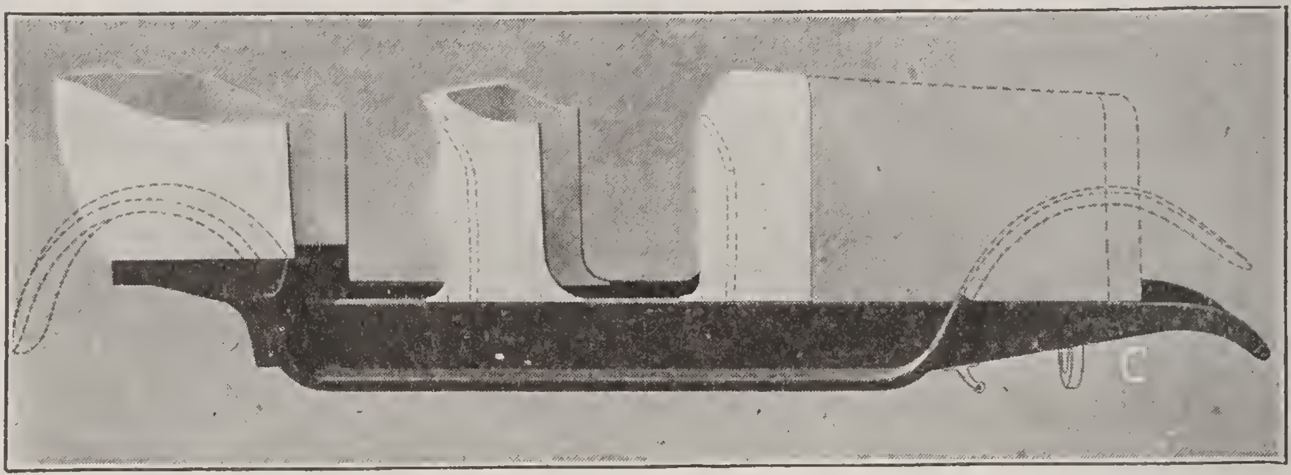


Fig. 381. Marmon Aluminum Frame, Showing Running Board Construction

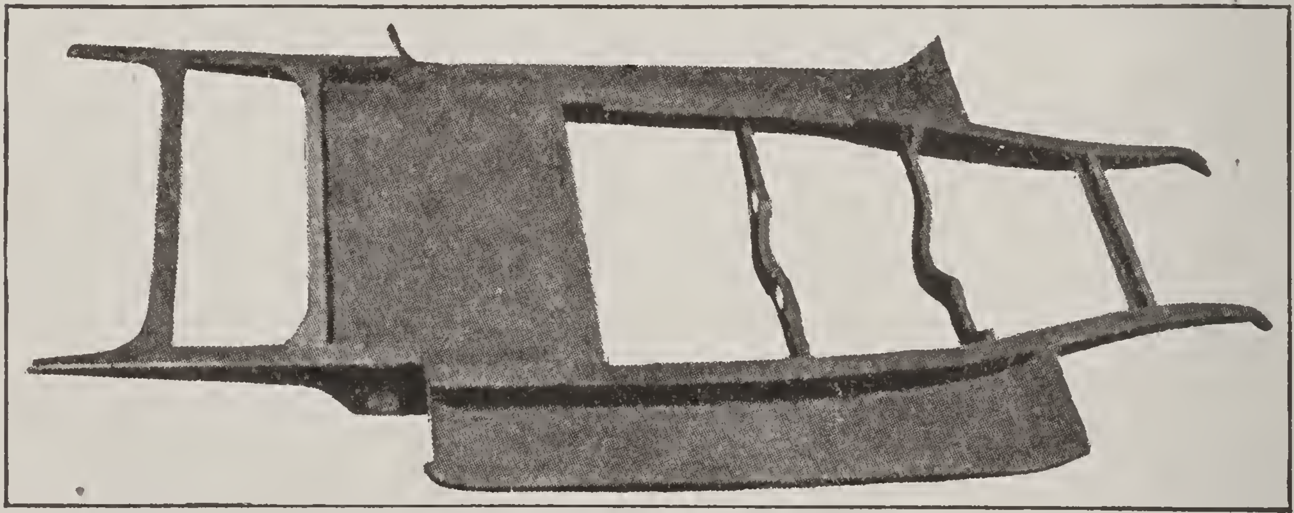


Fig. 382. Brush Pressed-Steel Frame
Courtesy of Hale and Kilburn Company, Philadelphia, Pennsylvania

Fig. 382 illustrates a type of frame similar to the Marmon, the Brush frame, controlled by the Hale and Kilburn Company, of Philadelphia.

Steel Underpans. The underpan has assumed a great deal of importance in the last two years, for makers have more and more realized that it is highly important to protect many of the parts from road dirt, flying stones, water, etc. Designers have, therefore, given considerable attention to its shape, size, and method of attachment. In some types, it apparently runs underneath both engine and transmission and is made more or less a part of the main frame. Therefore, its quick removal on the road would be difficult, if not impossible; yet road accidents sometimes make it necessary for the driver to take this pan off to get at the lower side of engine, clutch, or gear box.

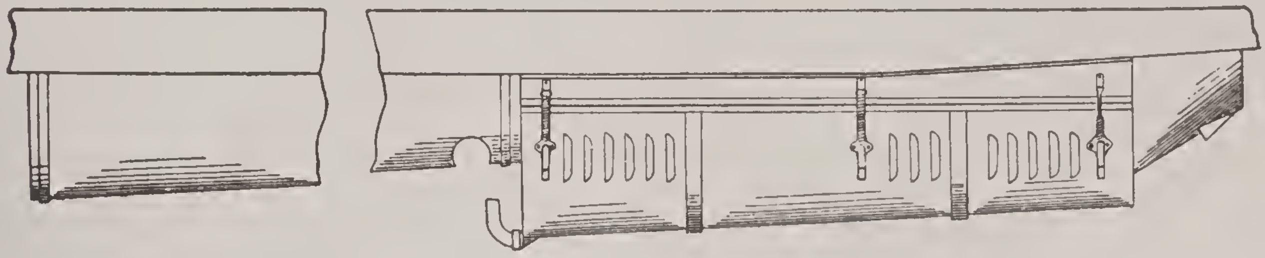


Fig. 383. Two-Piece Pressed-Steel Underpan Used on Winton Cars
Courtesy of Winton Motor Car Company, Cleveland, Ohio

For this reason, underpans generally resemble more closely that shown in Fig. 383. This is a side view, showing the semicircular form of the pans, as well as the two-piece construction. The forward part under the engine, which would be taken down fairly often, is held in place by three spring clips on either side. Lifting these clips off is only a second's work; in addition, there is a filler piece in front, helping to make the pan fairly air-tight. The depth of the pan increases slightly toward the rear, so as to form a slope down which liquids will drain; the rear end is fitted with an upturned elbow, so that it will not drip until it accumulates a considerable quantity of liquid. Continual dripping indicates a full charge, and the pan is drained by turning the elbow over.

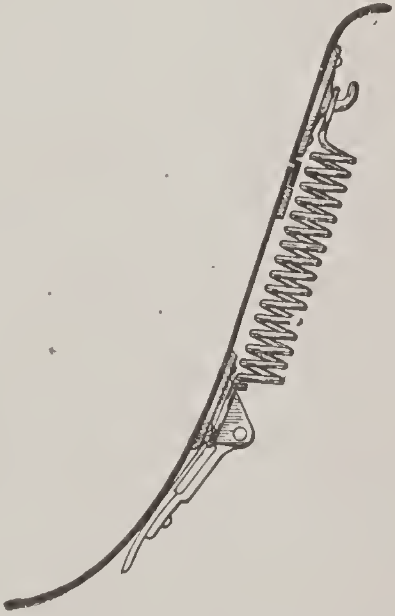


Fig. 384. Detail of Spring and Section of Winton Underpan

In Fig. 384, a detail of the arrangement of the pan shown in Fig. 383 is presented. This indicates both the permanent part of the underpan, which is attached to the frame, and the removable part, which is freed by loosening the spring clips shown.

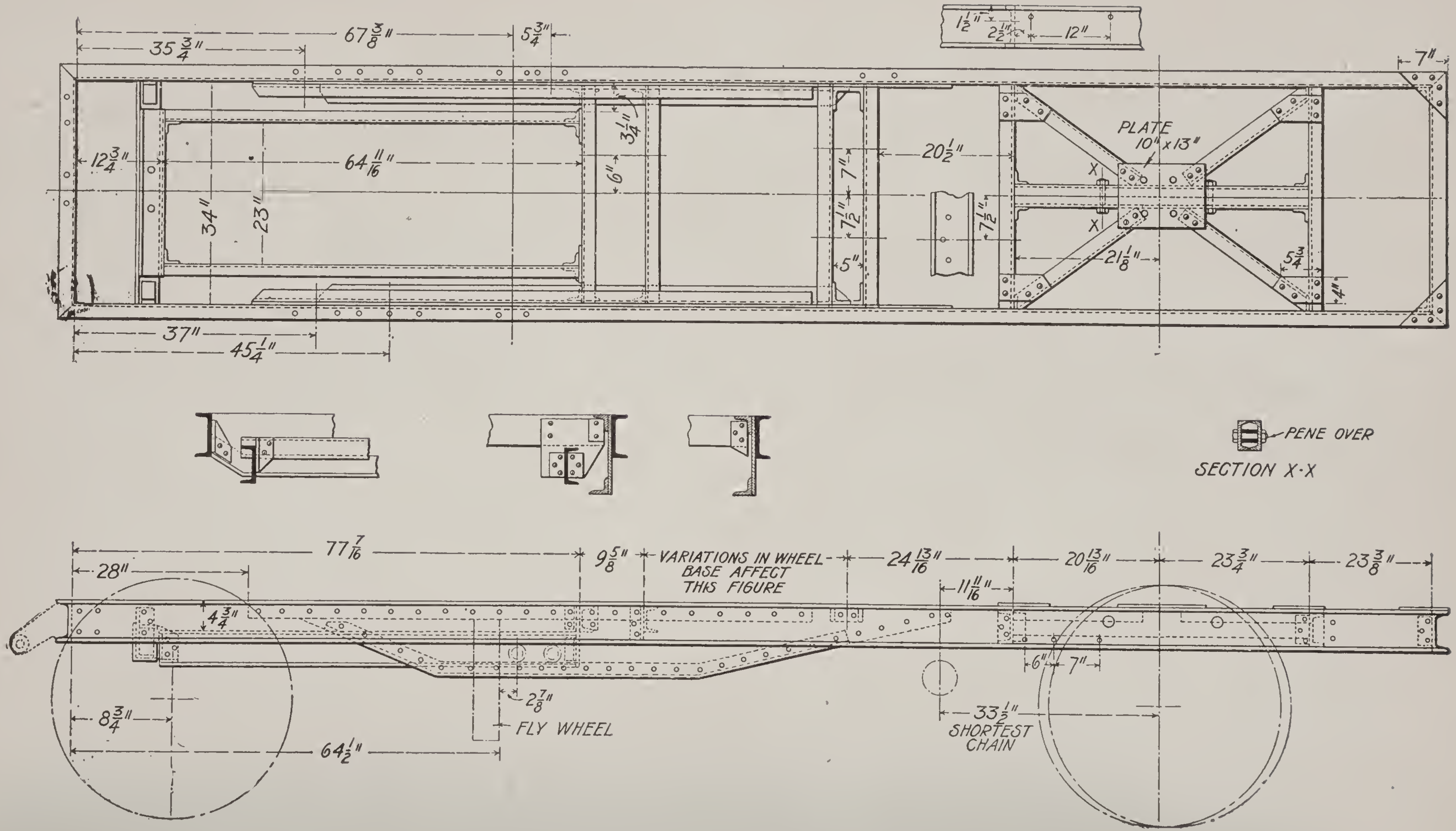


Fig. 385. Plan and Elevation of Frame of Heavy Truck

Commercial-Vehicle Construction. Commercial work, being rougher, harder, and cheaper work, changes the frame construction just as it does everything else about the car. In Fig. 385, a commercial-vehicle frame which brings out this point is shown. The main sills are 6-inch channels, while all of the other members are correspondingly large angles and channels. In one place the section consists of a box shape made up by bolting two large channels together, with the open sides in. The total overall length is not given, since this differs according to the variations in the wheel base; but, by a comparison of the figures given, it is seen that the frame shown is in excess of 210 inches long by about 37 inches outside width. This is about twice the total length of the average small car.

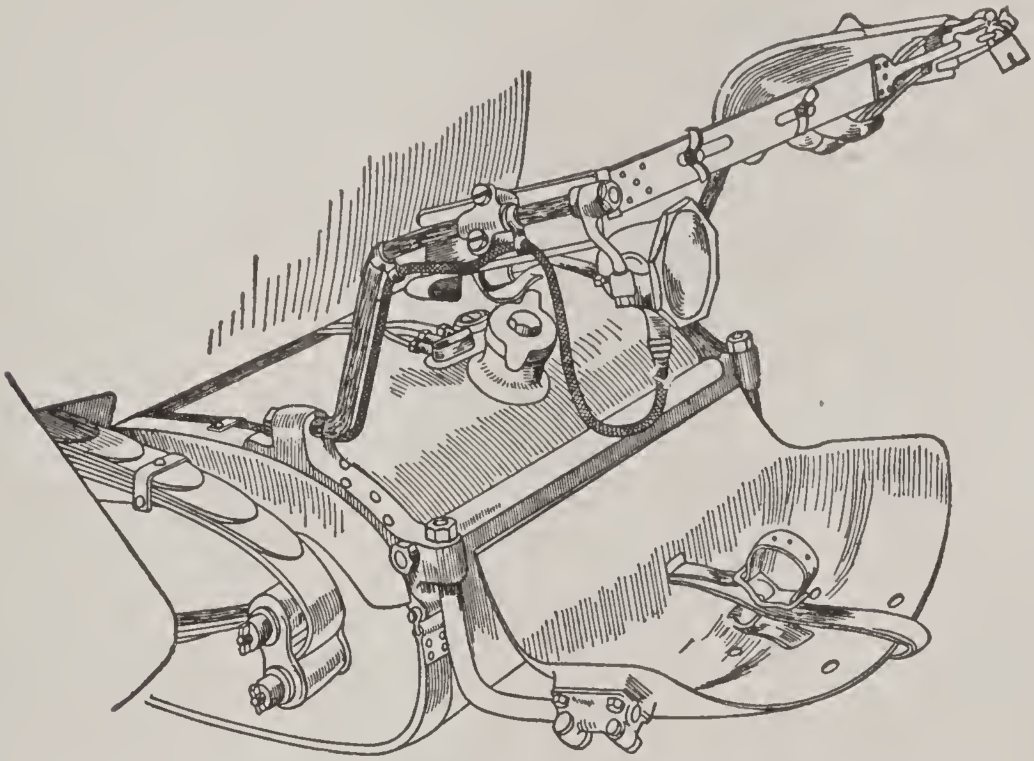


Fig. 386. Solid Rear Construction of Locomobile for Tires and Tanks
Courtesy of Locomobile Company of America, Bridgeport, Connecticut

In the bracing and arrangement of the different members, this frame shows other points of difference, the cross-members, for instance, being nine in number, not including the two diagonal cross-members. The longitudinal members, too, are eight in number, not counting the two diagonals.

Rear-End Changes. The locating of the fuel tank at the rear of the chassis—a practice that was brought into favor largely through the introduction of the vacuum system of fuel supply—has resulted in a number of changes to the rear ends of frames. The placing of the fuel tank at the rear is not new, and probably it would not have occasioned any change to the rear end of the frame were it not largely for the fact that the spare tires are now carried at the rear of the chassis. The tires themselves are not heavy enough to make it essential to strengthen the rear ends, but the very general use of carrying the spares inflated on demountable rims has added considerable weight to the rear of the chassis. This weight, coupled with that of a large fuel tank, has compelled makers to give more attention to the rear construction.

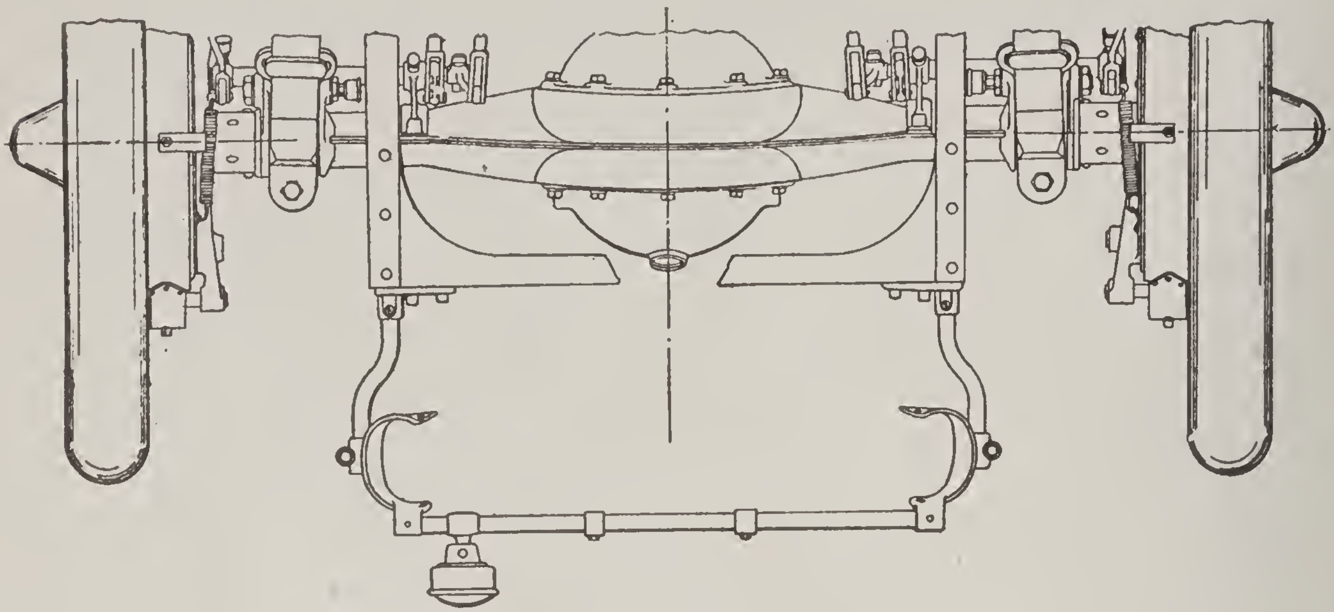


Fig. 387. Sketch of Rear-End Construction of Reo Car

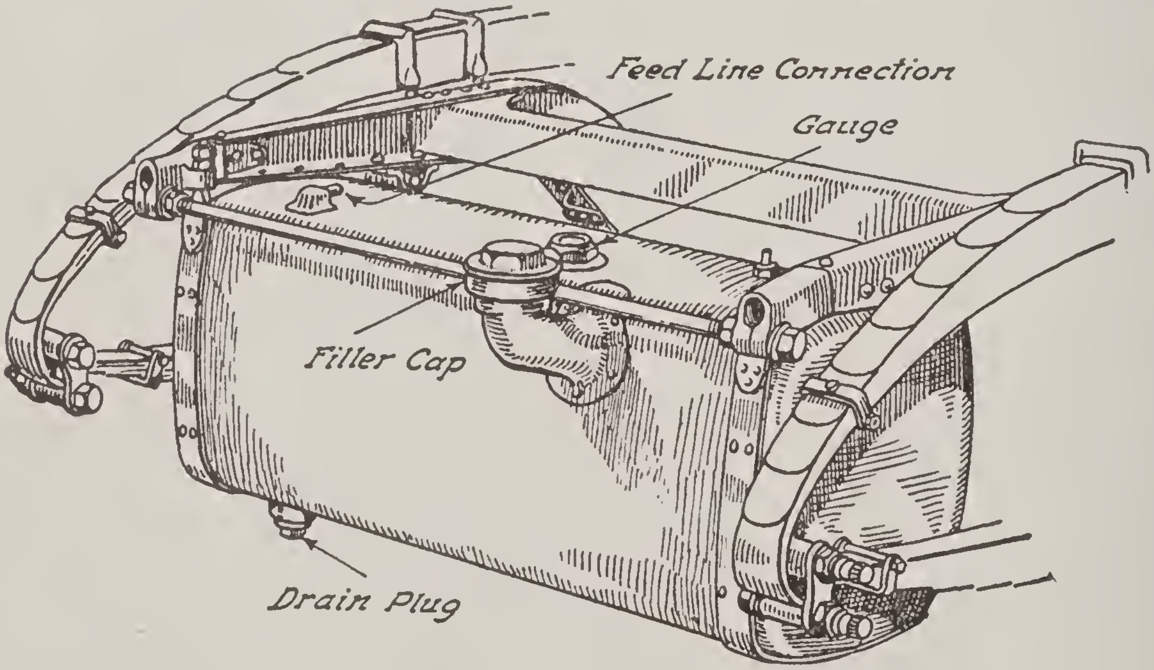


Fig. 388. Typical Rear-End Construction, Carrying Gasoline Tank

Provision is made for carrying the spare tires on the Locomobile chassis by means of an apron conforming in shape to the shoe. The three-quarter elliptic springs of the scroll type have ends attached to the outside of the main frame, which is carried back and serves as an extension for attaching the fuel tank. A cross-member is also utilized; it serves as a point of attachment for the two rods supporting the lower apron and for two upper rods as well. This design has merits in that the tire carrier is firmly anchored and serves to protect the fuel tank from injury possible in operating in crowding traffic where rear-end collisions are not uncommon. As may be noted, Fig. 386 shows the method of using an upper cross-member to prevent theft of the tires.

A different type of rear construction is shown in Fig. 387, a Reo. Here the rear cross-member is gusseted, and a pair of substantial arms are riveted to the cross-member. These arms serve as an anchorage for the tire holders which, in turn, have a cross-rod for protection. Still another design is shown in Fig. 388. Here the side rail of the frame projects back of the rear cross-member of the frame for a distance of about 12 inches. The fuel tank is suspended from these two extended frame members by means of steel straps which pass around the tank.

FRAME TROUBLES AND REPAIRS

The more usual troubles which the repair man will encounter are sagging in the middle; fracture in the middle at some heavily loaded point or at some unusually large hole or series of holes; twisting or other distortion due to accidents; bending or fracture of a sub-frame or cross-member; bending or fracture at a point where the frame is turned sharply inward, outward, upward, or downward.

Sagging. A frame sags in the middle for one of two reasons, either the original frame was not strong enough to sustain the load or the frame was strong enough normally, but an abnormal load was carried, which broke it down. Sometimes a frame which was large enough originally and which has not been overloaded will fail through crystallization or, in more common terms, fatigue of the steel. This occurs so seldom, and then only on very old frames, that it cannot be classed as a "usual" trouble; moreover, it cannot be fixed.

When a frame sags in the middle, the amount of the sag determines the method of repair. For a moderate sag, say $\frac{1}{4}$ to $\frac{1}{2}$ inch, a good plan is to add truss rods, one on either side. These should be stout bars, well anchored near the ends of the frame and at points where the frame has not been weakened by excessive drilling. They should be given a flattened U-shape, with two (or more) uprights down from the frame between them. The material for them should be stiff enough and strong enough to withstand bending and should be firmly fastened to the under side of the frame. The truss rods should be made in two parts with a turnbuckle to unite them, the ends being threaded right and left to receive the turnbuckle. When truss rods are put on a sagged frame, it should be turned over and loaded on the under side; then the turnbuckles should be pulled up so as to force the middle or sagged part upward a fraction of an inch, say $\frac{1}{8}$ to $\frac{1}{4}$ inch, and then the frame turned back, the other parts added, and the whole returned to use. A job of this kind which takes out the sag so that it does not recur is a job to be proud of.

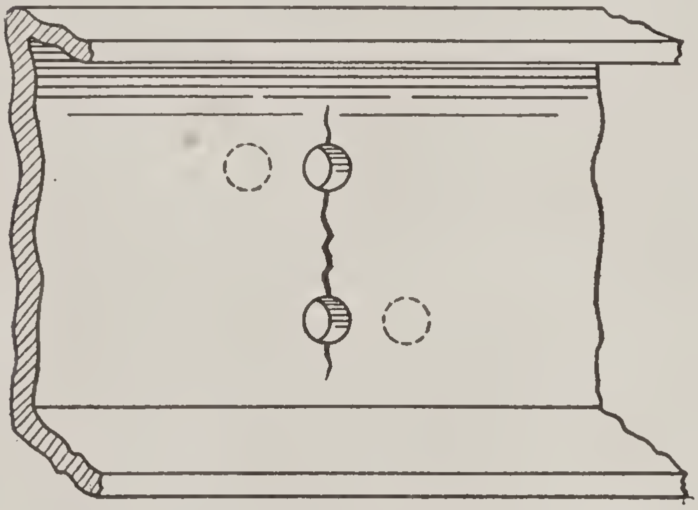


Fig. 389. Reboring Cracked Steel Channel

Fracture. Many frames break because too much metal was drilled out at one place. Fig. 389 shows a case of this kind. The two holes were drilled, one above the other, for the attachment of some part, and were made too large. They were so large that at this particular point there was not enough metal left to carry the load, and the frame broke, as indicated, between the two holes and also above and below. A break of this kind can be repaired in two good ways. The first and simplest, as well as the least expensive, is to take a piece of frame 10 to 12 inches long, of sufficiently small section to fit tightly inside this one. Drive it into the inside of the main frame at the break, rivet it in place firmly throughout its length, and then drill the desired holes through both thicknesses of metal.

This is not as good as welding. A break of this kind can be taken to a good autogenous welder who will widen out and clean the crack, fill it full of new metal, fuse that into intimate contact with the surrounding metal, and do so neat and clean a piece of work that one would never know it had been broken. When a welding job is done on a break like this, and no metal added besides that needed to fill the crack, subsequent drilling should be at an angle, to avoid a repetition of the overloading condition. In the figure, the dotted lines suggest the drilling. By staggering the holes in this way, there is a greater amount of metal to resist breakage than would be the case with one hole above the other—a method which might preferably have been used in the first place.

So much welding is done now, and so many people know of its advantages, that every repair shop of any size should have a welding outfit. A frame job is essentially an inside bench job, but a large number of cases of welding could be done directly on the car outside the building, particularly in summer when the outside air and cooling breezes are desirable. So, it is well to construct a small truck on which to keep the oxygen tank, acetylene cylinder, nozzle for working, and a fire extinguisher. One form of a truck is shown in Fig. 390. This truck is a simple rectangular platform with casters, a handle, and a rack to hold the tanks. It saves many steps and is particularly convenient in summer months. This outfit is essentially a home-made affair, but the gas-welding and electric-welding manufacturing companies have designed small outfits especially for automobile repair work, which would be preferable to the one in Fig. 390, especially where the amount of repair work warrants a reasonable expenditure for a welding outfit. A description of both gas and electric outfits and instructions for their use are given in the section on Oxy-acetylene Welding Practice.

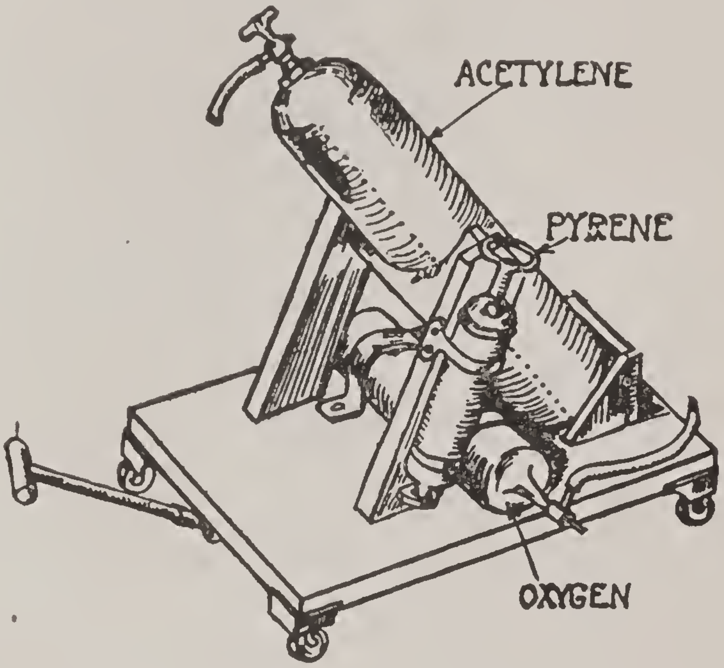


Fig. 390. Handy Oxy-Acetylene Outfit

Riveting Frames. *Tightening Rivets.* Rivets securing the corners of a frame or holding cross-members, gussets, and plates often work loose, particularly with the flexible type of frame previously alluded to. The location of the rivet and the accessibility of the part will determine how best to proceed with the work. The chief trouble experienced is that of placing a sufficiently solid article against the rivet while the other end is being hammered. As a rule, old axles, sledges, and hammers will serve under ordinary conditions, but these cannot always be used in a channel frame. One method is to employ an old anvil which is turned upside down and so placed in the frame that the flat end of the anvil is placed against the head of the rivet, while a rivet set is employed to set the rivet up snug. The horn of the anvil is allowed to rest on the other side of the frame. This method can be used for cutting off rivets as well as for tightening old ones. The anvil should be of sufficient length to rest on the frame as above described.

When an anvil is not available, the following method may be used with success. Take a ½-inch bolt and cut it off so that it will just go in the frame between the rivets. Slightly countersink the head of the bolt with a cold chisel. Put on the nut and slip in between the rivets and run the nut down until it expands tight in the frame. The depression in the head of the bolt, and the nut fitting around the opposite rivet head will keep it firmly in place while riveting. It is not always practical to attempt to tighten a rivet. The better method is to remove it, drill a larger hole and use a larger size rivet. Rivets are usually made of Norway iron. Heat to a red heat before using.

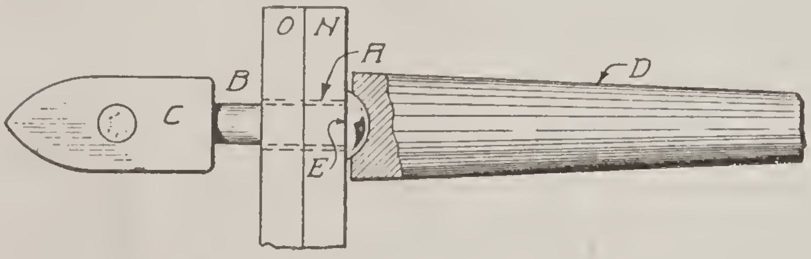


Fig. 391. Method of Riveting Frame

Riveting Methods. There are two methods of riveting, the driving in and the backing in. The latter method is shown in Fig. 391, and the two plates to be riveted are drilled in the usual manner, as shown at *A*, with the rivets a trifle smaller than the hole, placed as shown at *B*. With hot riveting, the hole should be about $\frac{1}{16}$ inch larger than the rivet, but with cold rivets, the opening should be such that the rivets will slide in. Instead of backing up the head of the rivet, a dolly is applied to the small end, as indicated at *C*, and the driving is done on the head of the rivet by a set *D* and a hammer. The energy of the hammer is applied through the set to the rivet, which is upset or enlarged, as it is unable to move because of the mass of metal in the dolly. The metal of the rivets expands sidewise at *A* and *B*, completely filling the space. A feature of this method is that a part of the hammer blow is expended in forcing the plate *N* into contact with the plate *O*. The metal at *B* is prevented from moving sidewise by a head formed at the dolly end of the rivet, and additional blows of the hammer tend to bring the plates closer and to hold them. The backing-in method is practical in making the various styles of rivet heads, particularly in making the thin, almost flush, head, and an advantage is that there are no reactionary stresses upon the thin head as would exist with the driven-in rivet.

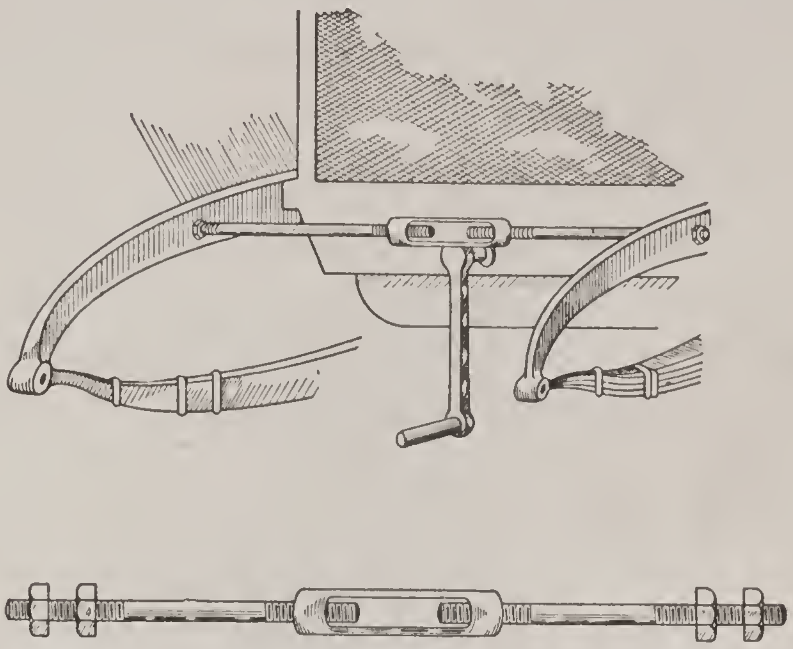


Fig. 392. Adding a Truss Rod to the Front of a Weak or Damaged Frame to Strengthen It and Preserve the Radiator

As there is more demanded of the rivet replacing the old member, it is important that the work be carefully performed. This applies to the holes in the plate. All sharp corners should be removed, as they afford an opportunity for the rivet to shear off by external stress or to fly off under internal strain. A reamer, drill, or countersink can be used in removing sharp corners. The face left need not be more than $\frac{1}{64}$ or $\frac{1}{32}$ inch wide, in order to greatly strengthen the rivet at its weakest point, or where the head joins the body. By slightly chamfering the corner of the plate, the rivet is given a corresponding fillet, which not only increases its holding power but serves to draw the plates together.

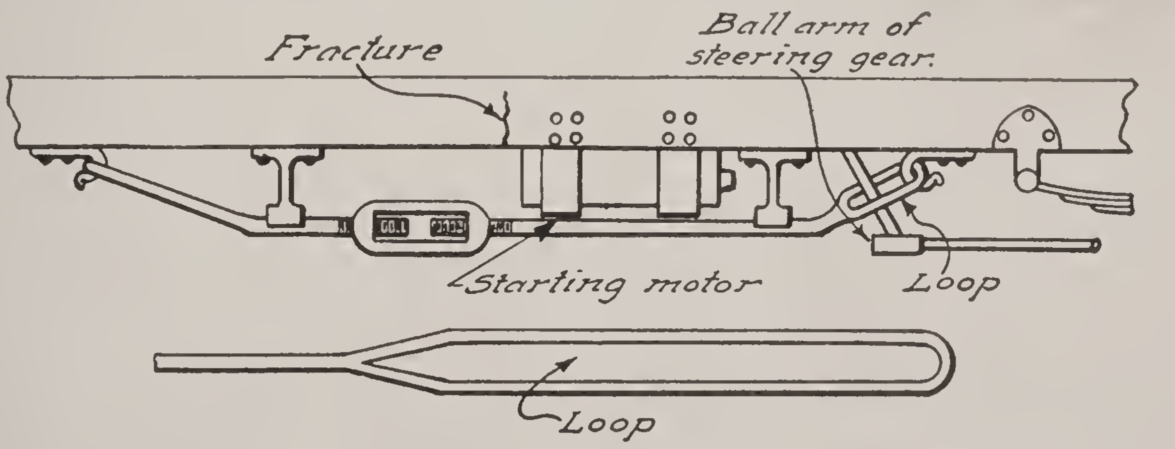


Fig. 393. Bracing Fractured Frame with Bar and Turnbuckle

Frame Bracing Methods. There are several methods whereby a frame that has been injured through collision or has sagged because of too light construction can be repaired. The front of the frame is the chief offender in this respect, and many times a leaking radiator is the result. When repairs to the radiator fail to cure the trouble, it may be assumed that the frame is at fault. A simple remedy is shown in Fig. 392 and consists in bracing the frame by means of a rod and turnbuckle. The rod should be about 2 inches longer than the width of the frame and threaded for about 3 inches on each end. The turnbuckle is not essential, but it simplifies the work. In installing the brace, the inside nuts are screwed on first and far enough to allow putting the rod in place. These nuts are next screwed out until they bear against the frame, and the latter is forced out until any pressure that may have existed on the radiator is eliminated. The outside nuts are then screwed up snug. The advantage of the turnbuckle is that adjustments may be made as required.

Fig. 393 shows a method of trussing a frame that was fractured by the stresses of the motor starter. Even after the fracture had been repaired, the driving gear of the starter would not mesh properly with the ring gear on the flywheel of the engine. As the movement was up and down on the frame, a truss was found necessary; while it was a simple matter to attach one end of the truss on the left-hand side of the chassis, the right-hand side was more difficult because of the proximity of the ball arm of the steering-gear lever. The problem was solved by forming a loop at one end of the truss of sufficient width and length to permit travel of the ball arm. By utilizing a turnbuckle the desired tension was obtained.

SPRINGS

Basis of Classification. The springs are important components of the chassis; for while the frame supports the power plant, clutch, and gearset, it is, in turn, supported upon the springs. The tendency at present is to design the frame and spring suspension so that the rear springs are placed very close to the rear wheels. In some cases, the frame is wide at the rear and is directly over the springs. Springs may be divided into seven general classes as follows: semi-elliptic, the full-elliptic, the three-quarter elliptic, the platform type, the cantilever, the quarter-elliptic, the coil, and combinations of these. The full-elliptic spring is made up of two sets of flat plates, slightly bowed away from each other at the center and attached together at the ends. When these are used, the centers of the springs are attached top and bottom, respectively, to the frame and axle. With half of the top of the spring cut away, and the cut, or thick, end attached to the frame, this spring becomes a three-quarter elliptic. When the whole top of the spring is cut away, so that the spring is but a series of flat plates, bowed to a long radius, this becomes a semi-elliptic spring. By turning the semi-elliptic spring over, it becomes a cantilever when its center and one end are attached and the load applied to the other end. The quarter-elliptic is but a quarter of a spring, while the platform consists of three semi-elliptics—two as side members in the regular position, while the third is used as a cross-spring, being inverted and attached at the center to the rear end of the frame and at its ends to the side members. The coil form requires no explanation and is not now used on cars. In addition, these forms are modified by scroll ends and various attachments.

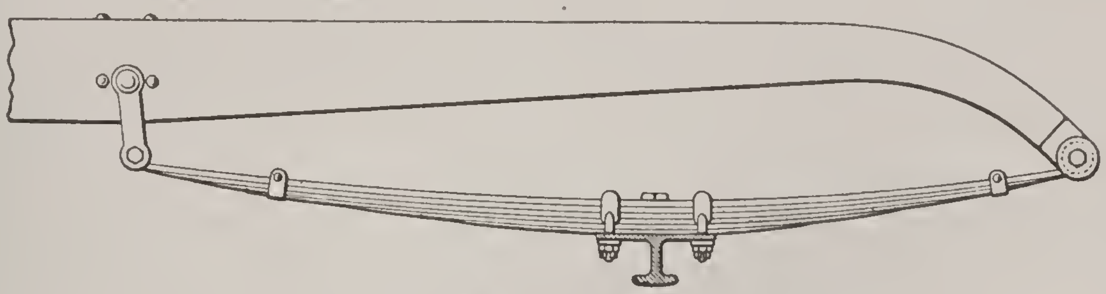


Fig. 394. Typical Semi-Elliptic Front Spring

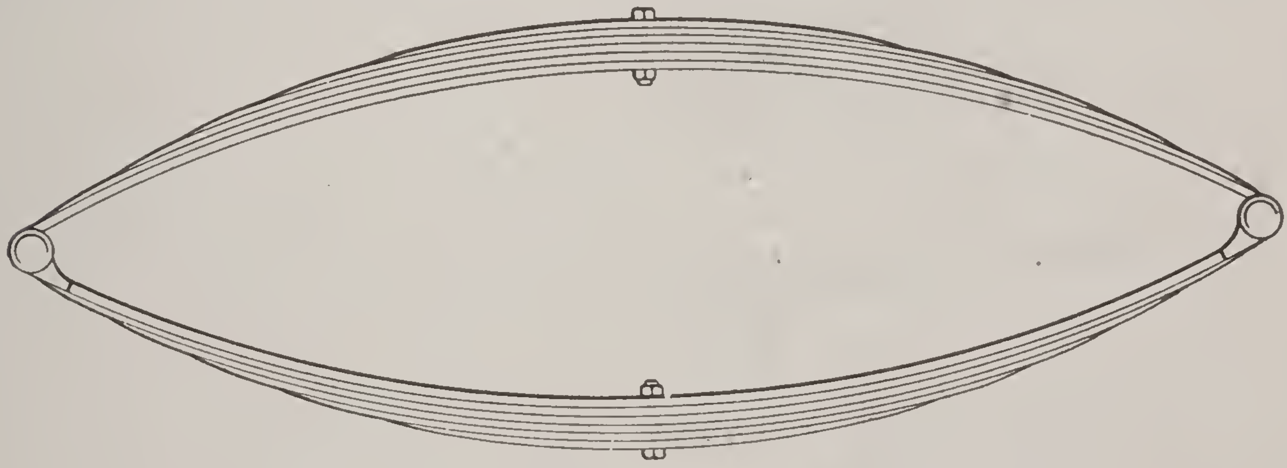


Fig. 395. Typical Full-Elliptic Front or Rear Spring

Semi-Elliptic. Fig. 394 shows a front spring of the semi-elliptic type, the form which is used now for almost every front spring. This is a working spring of the usual type, fixed at the front end, shackled at the rear end, attached to the axle in two places, and with two rebound clips in addition. The latter are put on the springs to prevent them from rebounding too far, in the case of a very deep drop. In some cases, as high as four, six, or eight of these clips may be used. Many other springs are made with ears, these being clipped over the next lower spring plate, the final result being the same as the use of many clips; but with improved appearance.

Full=Elliptic. Full-elliptic springs are the oldest form known. Fig. 395 shows the construction of this type, the upper and lower parts being pivotally connected at the ends. A slight modification of this form, known as the scroll-end full-elliptic type, is in more extensive use than the full-elliptic plain type. As Fig. 396 shows, the ends of the upper leaves are bent over. Each carries an eye, which is connected to the eye in the end of the upper leaves of the lower half of the spring by means of a shackle. This construction makes a very soft-riding spring.

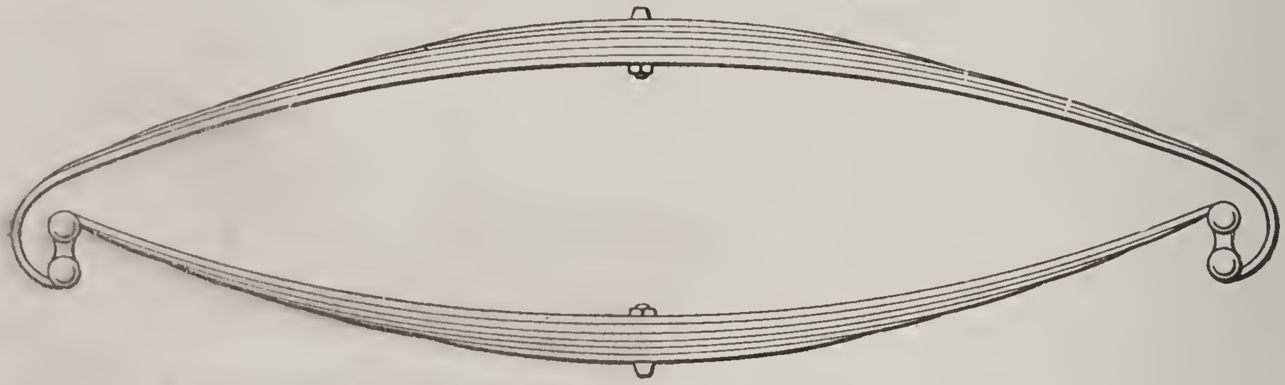


Fig. 396. Full-Elliptic Spring with Scroll Ends

Three=Quarter Elliptic. Very much like Fig. 396 is the form known as the three-quarter elliptic spring, the one having scroll ends being shown in Fig. 397. This form of spring is fastened at three points. The lower part of the spring is shackled at the front end, fixed to the axle at the center, and shackled to the upper part of the spring at the rear. The upper part of the spring is fixed to the frame at the upper front end and shackled to the lower part at the rear. Fig. 407 shows another example of the three-quarter elliptic spring, which may differ in practice, as some three-quarter springs are not scroll ended.

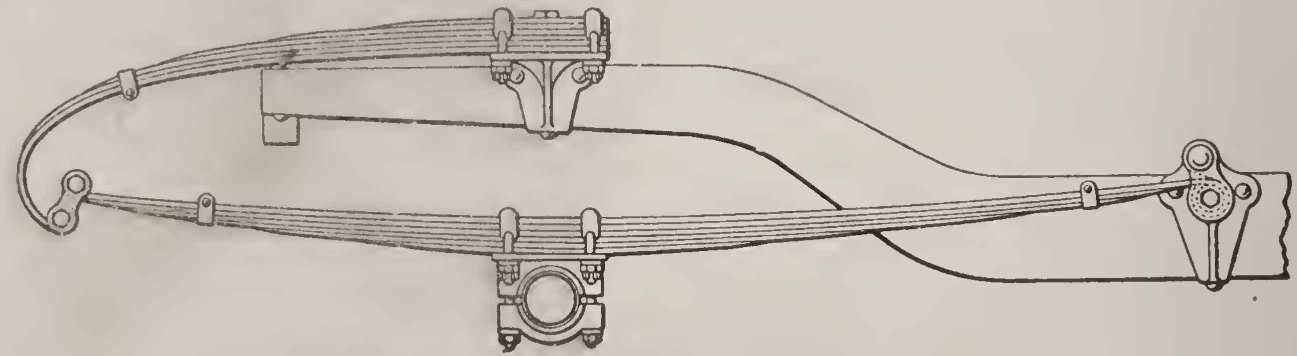


Fig. 397. Three-Quarter Elliptic Rear Spring with Scroll Ends

This form of spring is growing in favor daily, a greater number being used this year than last, while designs for next year show a still greater increase. One reason for this increase is the great increase in the number of dropped frames, that is, frames unswept at the rear. To this form of frame, the three-quarter elliptic spring is very well adapted and makes a very natural, very good, and very easy-riding combination.

Platform. The platform type of spring is used a great deal on large cars, as well as on very heavy trucks, on account of its ability to carry heavy loads well, and also on account of its flexibility. As may be seen in Fig. 398, it consists of three semi-elliptic springs shackled together at the corners. The rear cross-spring is usually made shorter than the two side springs, while the latter are set off center, making the front of the spring, that is, the part forward of the point of attachment to the axle longer than the part to the rear. There are two reasons for this: First, the front end acts somewhat as a radius rod, the rear end of the frame rising in an arc of a circle whose radius is the front half of the spring; second, this plan distributes the spring action equally in front of and back of the axle. Since the rear cross-spring is fastened to the frame in the center, each half of it is considered as a part of the side spring to which it is shackled. Thus, the total length of the side spring in front of the axle is the measured length of the side spring, while the total length of the side spring back of the axle is considered as the side length plus half of the cross-spring length. The center point, or point of axle attachment, is not moved so far forward as to make these two lengths equal, but in a proportion which may be derived thus: Assume a side spring 42 inches long and a cross-spring 35 inches long; then the spring would be set out of center some 4½ inches, making the front length about 25½ inches, while the rear length would be 16½ inches plus half of the rear spring, or 17½ inches, making a total of 34 inches. This would give a ratio of 25½ to 34, or 1 to 1.333. If the side members were 50 inches, the ratio would be about 1 to 1.25, and for side members shorter than 42, the ratio would be about 1 to 1.5.

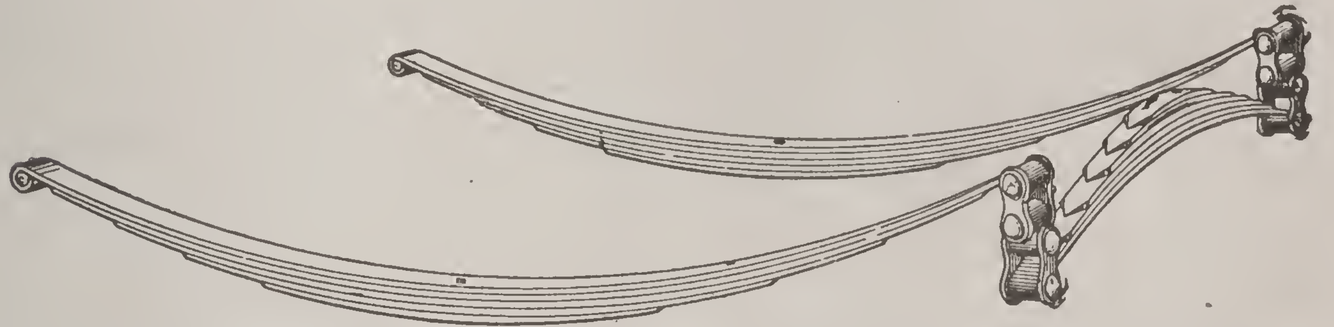


Fig. 398. Platform Springs, Showing How Side- and Cross-Springs Are Shackled Together

Cantilever. The cantilever is, in appearance, a semi-elliptic spring turned over. It gets its name, however, from the method of suspension, which is quite different from that of any form of semi-elliptic spring. Moreover. as a part of this suspension, at least one end of the cantilever and sometimes two are finished up flat and square to slide back and forth in a groove provided for that purpose, a bolt through a central hole preventing the spring from coming out of its guide. One form, shown in Fig. 399, has a fixed attachment to the rear axle, a pivoted attachment to the frame at its center (or slightly beyond the center), and a sliding attachment to the frame at its forward end to take care of the increase in length and of the forward movement necessary when the rear wheels rise.

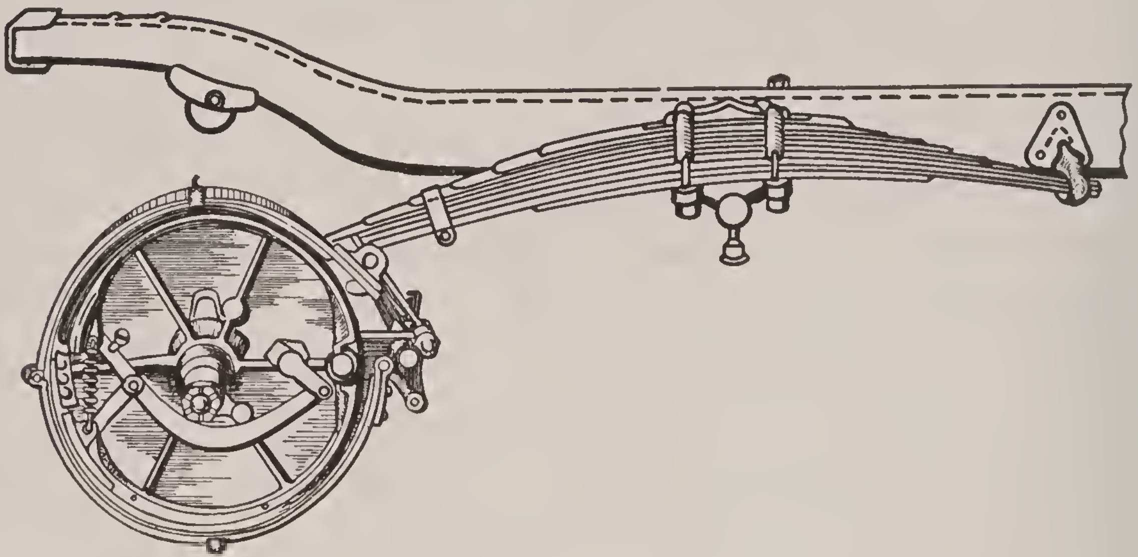


Fig. 399. Cantilever Rear Spring Used on King Cars
Courtesy of King Motor Car Company, Detroit, Michigan

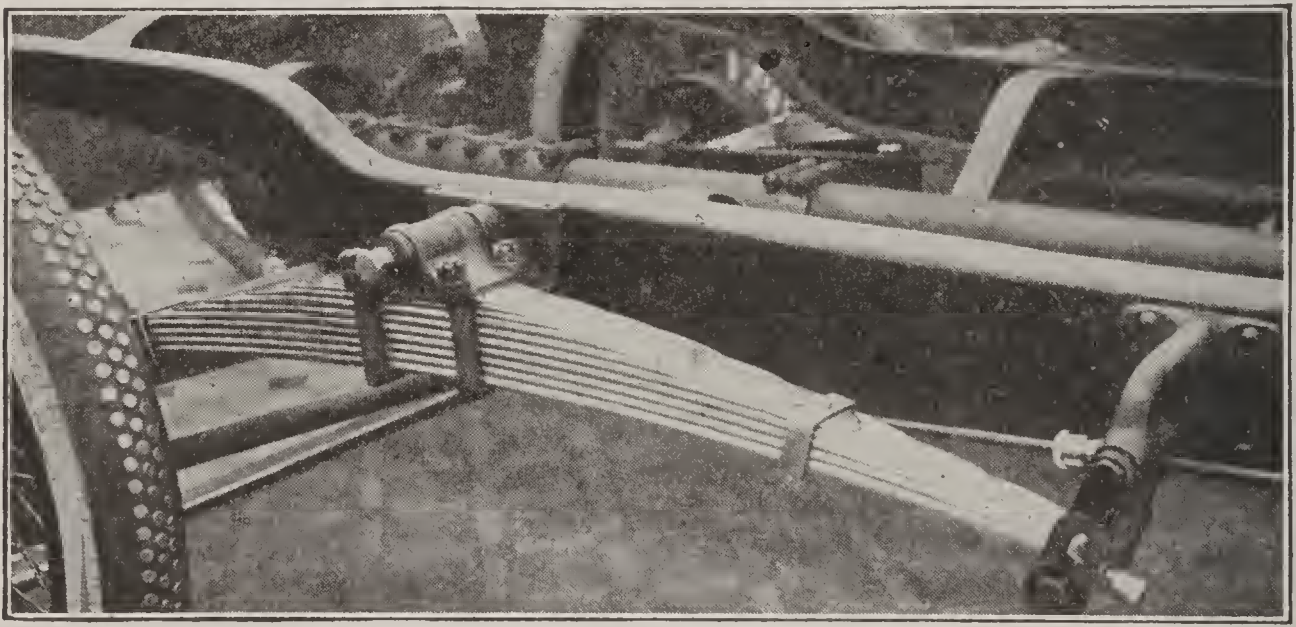


Fig. 400. Front End of Cantilever Spring on Siddeley-Deasy (English) Car

Another form of cantilever is that shown in Fig. 400. This is the rear spring on the Siddeley-Deasy (English) car and, like that of the King, is pivotally mounted on the frame just forward of its center. Unlike the King, however, the forward end of the spring has a shackle which permits it to swing when the rear axle rises or falls. This shackle is a very interesting feature of this installation, having an adjustment which is most unusual for a shackle, Fig. 401. Note how the outsides of the shackle have a series of grooves, into which the head of the shackle bolt on one side and the washer on the other, fit. By setting these in the desired grooves and tightening the nut, the position is fixed. If this does not give the proper throw, it is a simple matter to remove the nut and make a new adjustment.

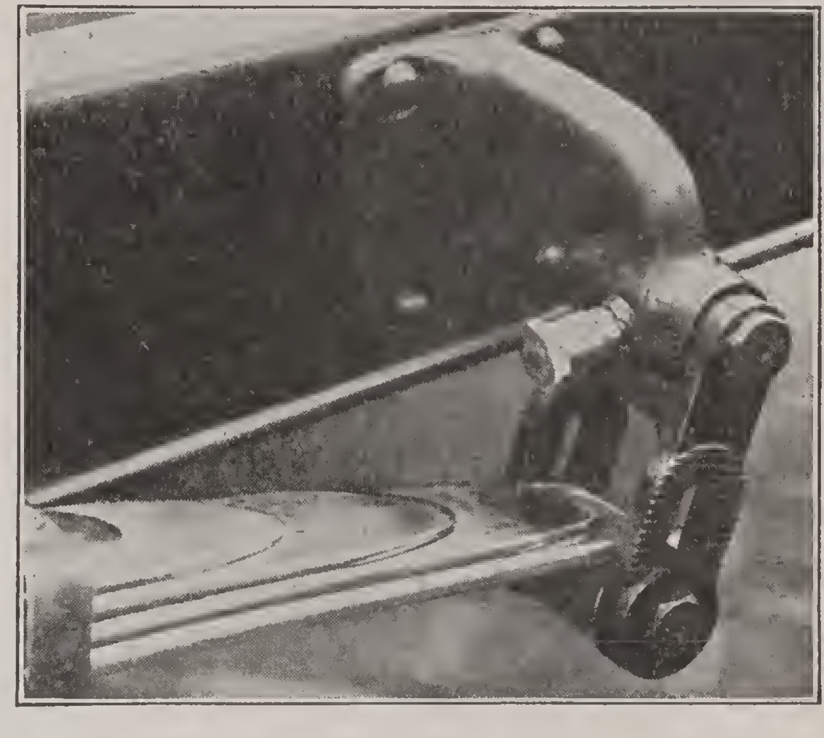


Fig. 401. Detail of the Adjustable Shackle on Siddeley Cantilever Spring

In France, a form of double cantilever has been tried out with success; this form consists of a pair of cantilevers, one above the other, separated at the center by a carefully sized spacing block, which is pivotally attached to the frame. The rear ends are attached above and below the axle, while the front ends are attached to two fixed points. Although the ends are made much thinner and more flexible than those just shown, it should be noted that both of them are fixed. The rise and fall of the wheels must be taken up by the springs themselves, the pivot in the center simply distributing the distortion over both the front and rear halves.

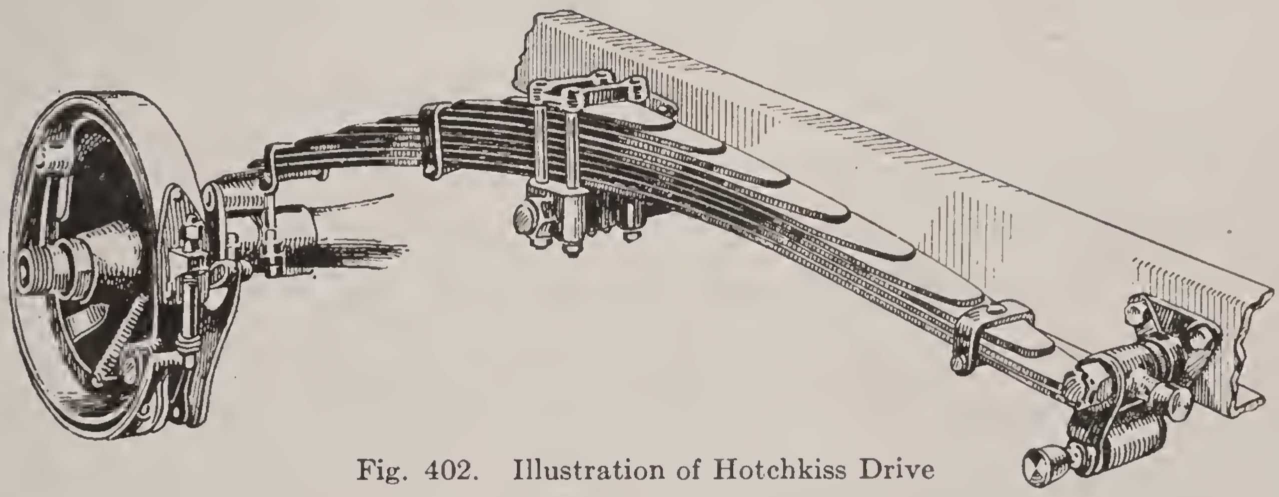


Fig. 402. Illustration of Hotchkiss Drive

Advantages of Cantilever. The advantages of the cantilever spring are the smaller unsprung weight and the reduced manufacturing cost for a given amount of flexibility. Another advantage is the absence of sharp rebounds and a greater deflection for a given load and length of spring; it also obviates the cut in the body required with the three-quarter elliptic spring. When the cantilever takes the driving strain, the main leaf is usually stiffened and, being stronger sidewise, it eliminates a good deal of the side sway. With torque rods, the main lead may be made lighter, as the starting, the braking, and the torque act through the torque rods. Since there is more metal in the line to the thrust, they are especially suitable for taking the thrust, and not quite as efficient in taking the torque.

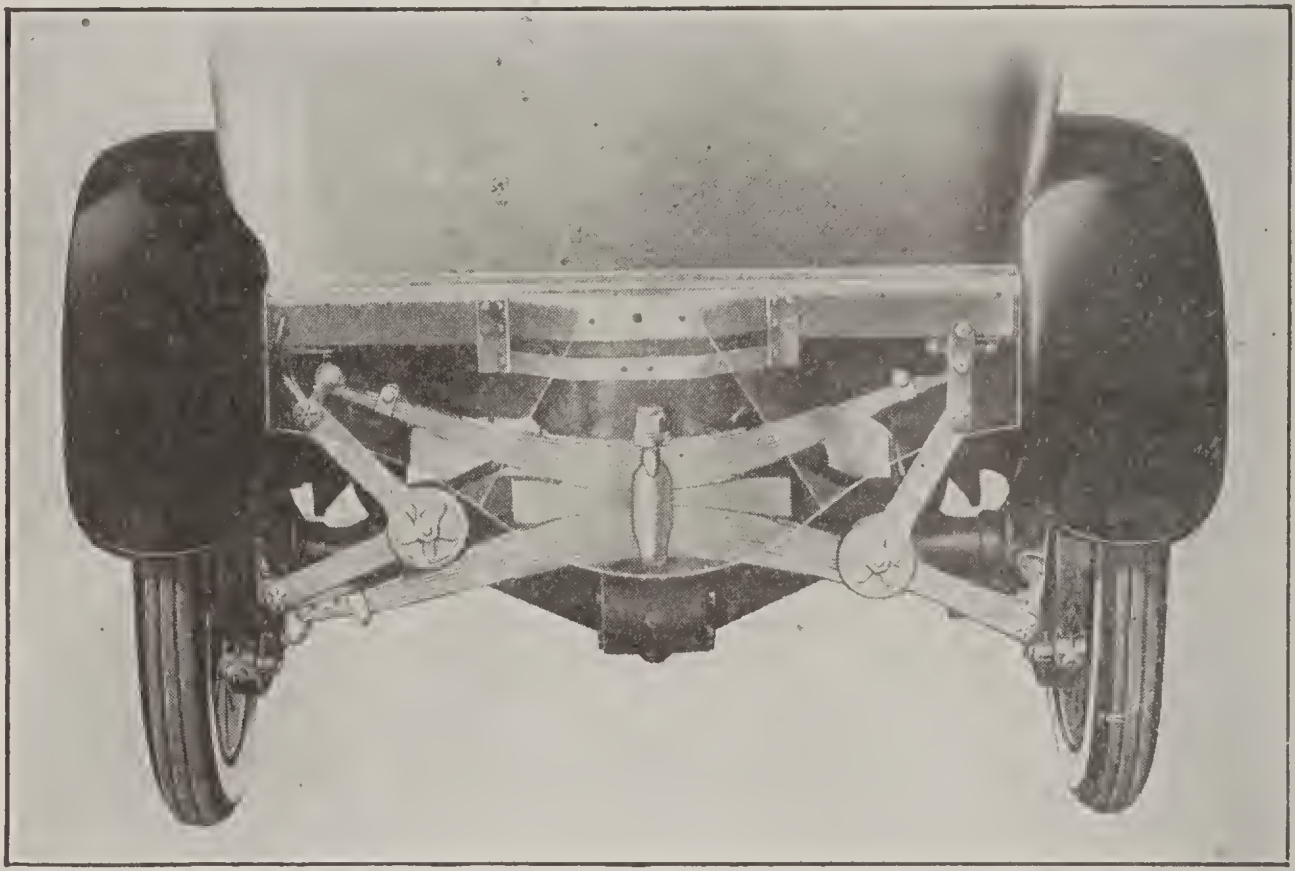


Fig. 403. Unique Rear Spring of Marmon Cars

Hotchkiss Drive. The adoption in 1915 of the Hotchkiss drive, Fig. 402, in which the rear axle is connected with the frame through the chassis springs only, making the springs perform the functions of torque and thrust, is a radical departure from previous forms. The objection that it subjected the springs to unnecessary strains has not been sustained in practice, which has shown that a slight yielding of the rear axle when starting and braking, by a certain flexure in the springs, has reduced the stresses upon the transmission members.

In the Hotchkiss drive, the springs are rigidly attached to the rear axle, while the front end of the spring is secured to the frame with a proportionately large bolt through which the drive is transmitted. Users of the drive claim that it is quieter, that the car holds the road better, that it is more flexible, and that it avoids the road shocks which are transmitted through stiff torque members from the axle to the frame. Makers who drive through the springs and employ other torque members claim that they are not sacrificing flexibility in driving while eliminating a certain side sway and other strains prevalent when the springs perform the functions of the torque. In the Hotchkiss drive, two universal joints in the drive shaft are used.

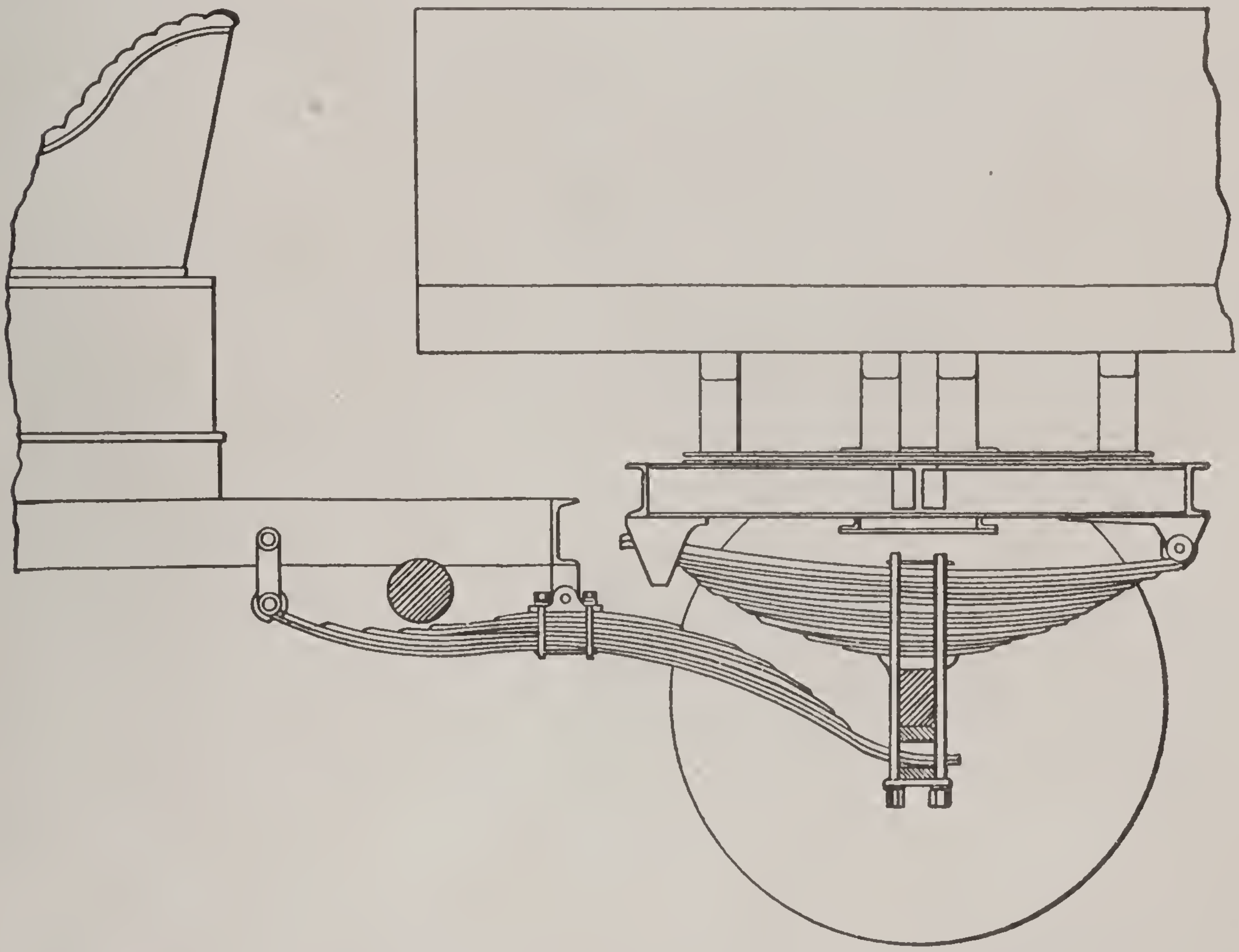


Fig. 404. Combination Cantilever and Semi-Elliptic Spring on Tractor

Unconventional Types. *Marmon.* A departure from conventional practice is the spring used on the Marmon car and shown in Fig. 403. It is a double-transverse construction, consisting of semi-elliptic springs bolted together at the center, with a curved block, or hard-maple cam, between them. This cam varies their stiffness, the spring automatically becoming stiffer as the load increases. Under normal load, the stiffness is about 170 pounds per inch, but as the springs are compressed the stiffness will reach 400 pounds. They are shackled at one side and fixed at the other, obtaining a perfectly parallel motion to the frame. There is said to be no roll as is sometimes found with transverse springs.

Knox Tractor. An unusual method of suspension is that employed on the Knox tractor, a combination of a cantilever and semi-elliptic spring at the rear end of the frame. The design shown in Fig. 404 includes heavy semi-elliptic springs, which are attached to the rear axle by long clips and carry the fifth wheel of the trailer. There is no connection between the springs and the tractor frame, so they carry the weight of the trailer and load only. The tractor frame is mounted on a cantilever spring having a pivot near its center and a shackle at the front end. The rear end bears on a seat clipped to the rear axle. This obtains a flexible mounting for the tractor and also permits the carrying of very heavy loads on the trailer.

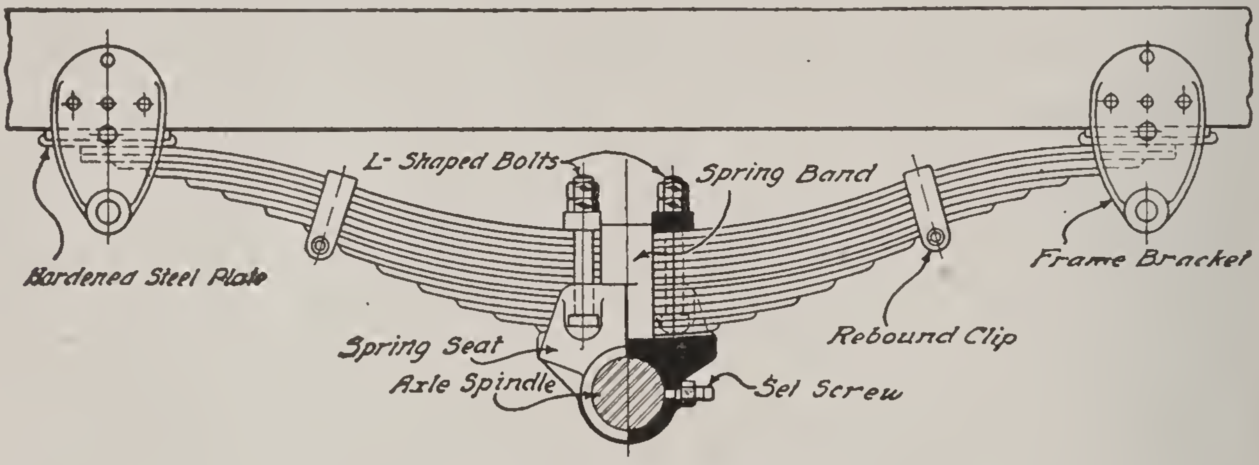


Fig. 405. Rear Spring of Six-Ton Truck

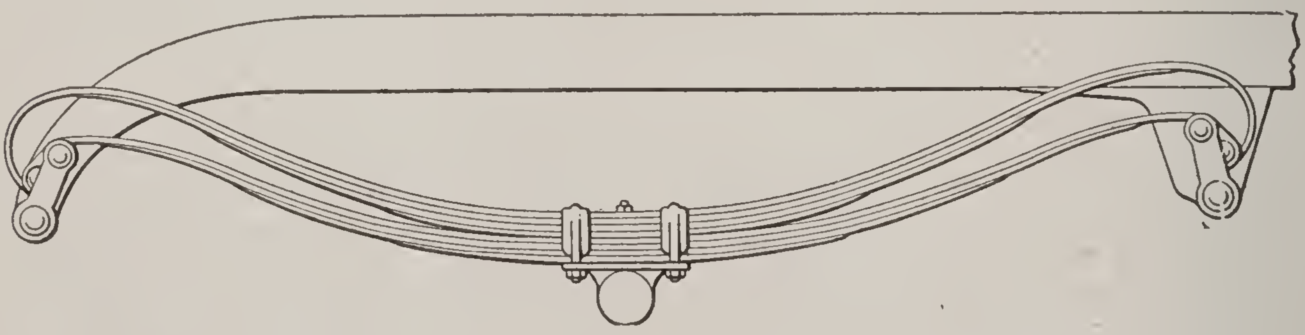


Fig. 406. Special Semi-Elliptic Rear Springs Formerly Made for Winton Cars
Courtesy of Perfection Spring Company, Cleveland, Ohio

Semi-Elliptic Truck Spring. The semi-elliptic spring is a favorite with makers of commercial vehicles. It is simple, and if the length, width, and other dimensions are proportioned correctly, it is a most satisfactory method for both front and rear suspension. Fig. 405 shows a rear spring for a 6-ton truck, the method of shackling, and how it is mounted on the axle by means of a spring seat.

Winton. Many makers use their own special form of springs. Fig. 406 shows the spring formerly used on the Winton cars, a type which might be described as a double-purpose spring. It was made in two parts, the lower part consisting of a regular semi-elliptic flat spring, while the upper part was a semi-elliptic flat spring with scroll ends. The central part of the spring was treated as one, being attached to the axle in the usual manner; the ends, however, had a peculiar appearance, because the upper and lower halves of the spring were of different shape. The scroll end of the upper part was supposed in itself to absorb many of the small road shocks. The spring was loosely attached to the frame at each end by means of a double shackle, made necessary by the double action of the spring; the tendency to flatten out increased its length, thus calling for a forward motion of the front and a backward motion of the rear ends, while the different lengthening action, owing to the difference in the lengths of the two parts of the spring itself, resulted in a turning about a different point.

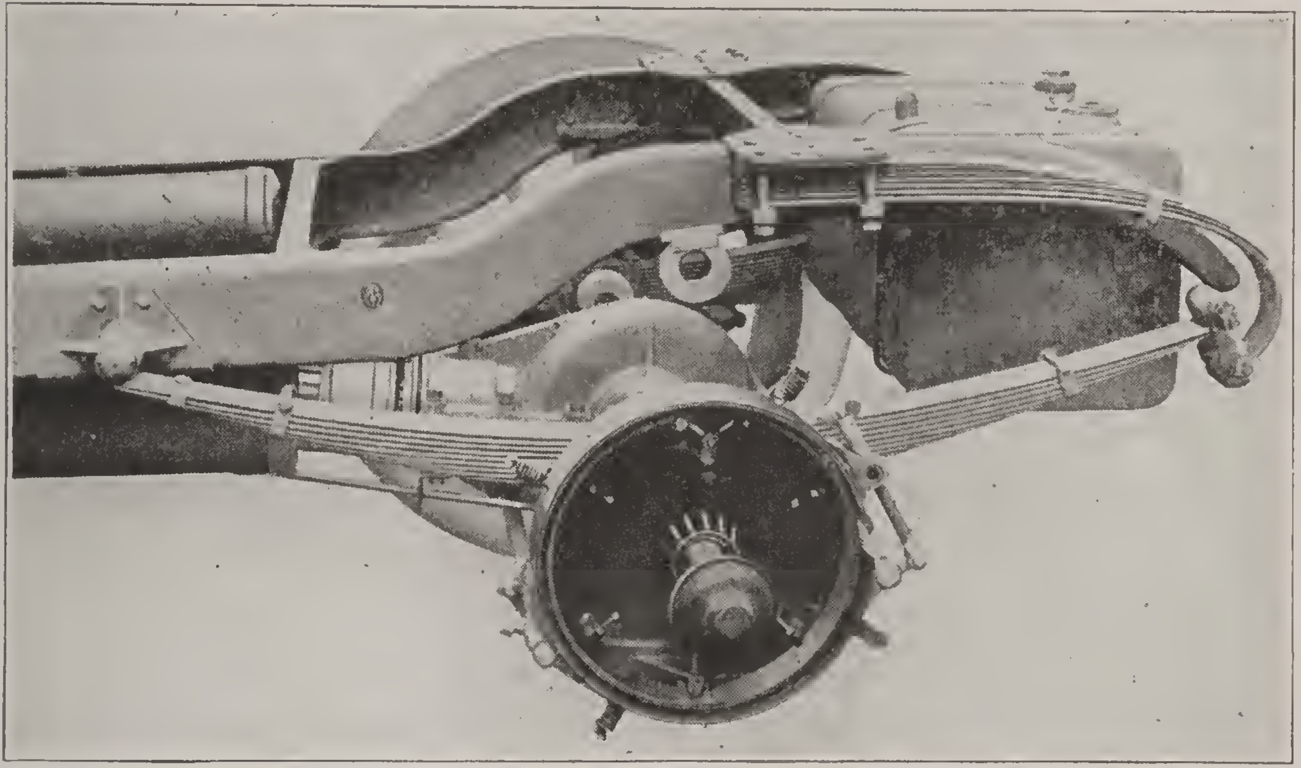


Fig. 407. Three-Quarter Scroll Elliptic Springs on Winton Car

For comparison with this earlier Winton spring, the latest form is shown in Fig. 407. It will be seen that the three-quarter elliptic form has been adopted, with a kick-up at the rear end of the frame. If the two types are compared somewhat closely, it will be seen that the only change in the frame part is the kick-up. The new springs show the scroll ends to which Winton has always been partial.

Ford. The form of the Ford spring has always been distinctly different. Fig. 408 shows the front and Fig. 409 the rear spring used on Ford cars, the distinction in the front spring being principally in the use of a single ordinary inverted front spring set across the frame on top of the axle, where most makers use a pair of side springs set parallel to the frame. This form is simple and cheap to make and assemble, the cost of the spring itself, and the work of putting it on being just about half that of the spring attachment of the ordinary two-spring type. On the other hand, excellent riding qualities are claimed for it. A second distinction is that the spring is an inversion of the usual semi-elliptic type, the set of the spring being downward instead of upward. A third claim to distinction is in the use of vanadium steel, which, it is claimed, has a higher tensile and compressive strength than any other steel, and it is practically unbreakable in torsion. This steel is also being used in many other parts, such as crankshafts, camshafts, fender irons, frames, driveshafts, etc., resulting in a very light-weight car, since the greater strength of the material allows the use of smaller sections for equivalent strength.

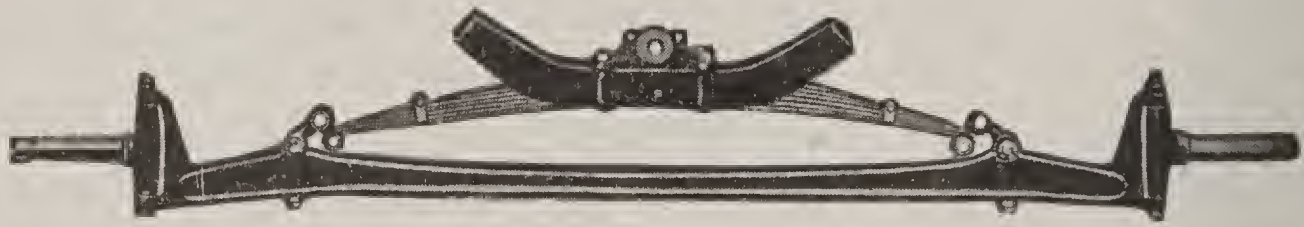


Fig. 408. Special Vanadium Front Springs for Ford Cars
Courtesy of Ford Motor Company, Detroit, Michigan

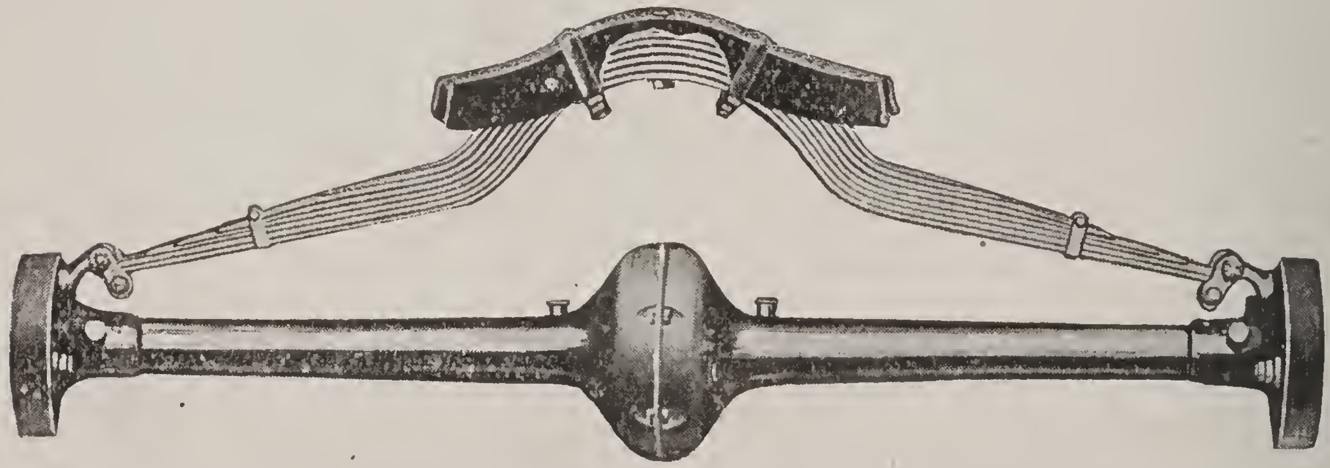


Fig. 409. Rear Springs of the Ford Car

The Ford rear spring has all the claims to distinction of the front spring, and, in addition, a hump at the center. Fig. 409 shows this hump clearly, the rear-frame cross-member being only partly shown. It will be noted that both ends of both springs are shackled, the construction necessitating it. These springs represent quite a radical departure, the success of which has been proved in actual practice.

Locomobile. Fig. 410 shows the three-quarter scroll elliptic rear spring used on the Locomobile, also the method of shackling both ends of the spring, and the use of a considerable extension beyond the spring clip of the two upper leaves. Fig. 411 illustrates the Locomobile front springs, the upper spring being used on the 1916 model, and the lower one on the 1917 model. As may be noted, the later type is 2 inches longer and also flatter, and the distance between the spring bolt and eye of the shackle is less in proportion to the 1916 design. It was found that the jerky action and fore-and-aft pitching of the axle were eliminated by this construction, greatly improving the riding qualities of the vehicle.

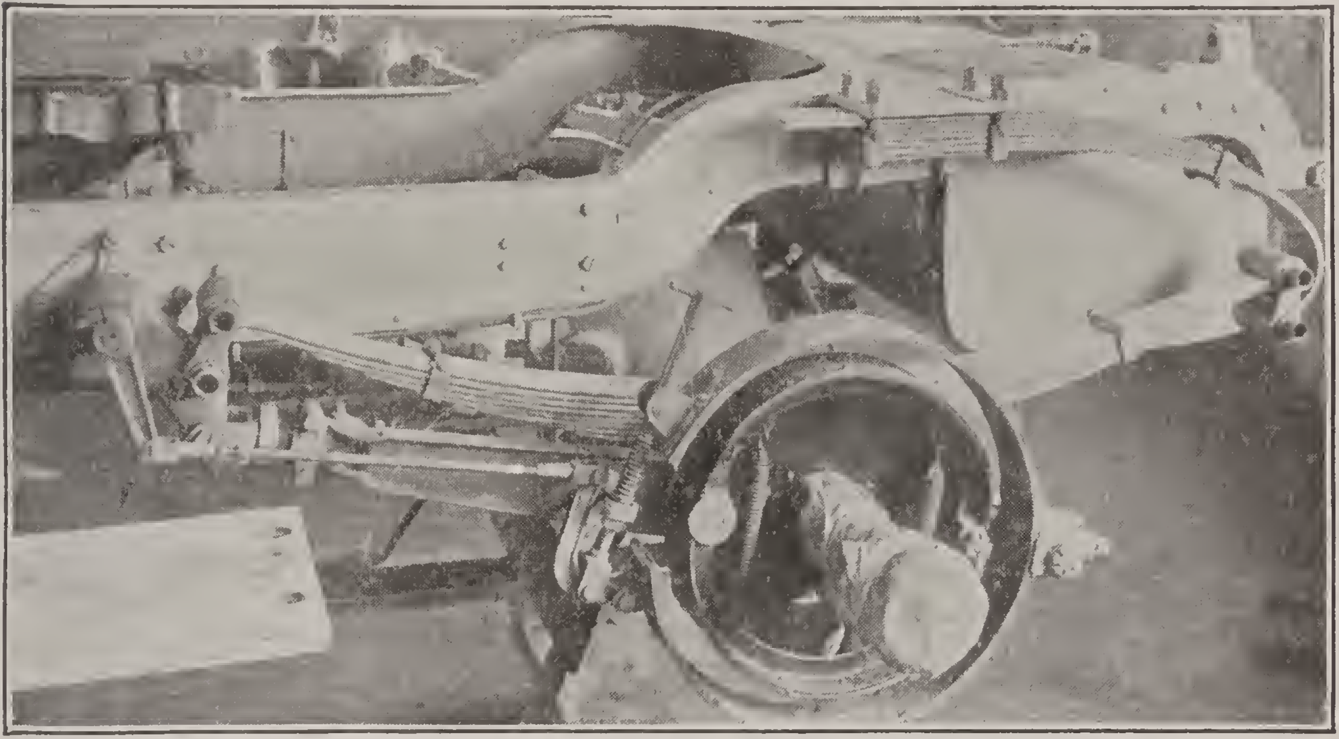


Fig. 410. Three-Quarter Scroll Elliptic Spring Used on Locomobile Cars

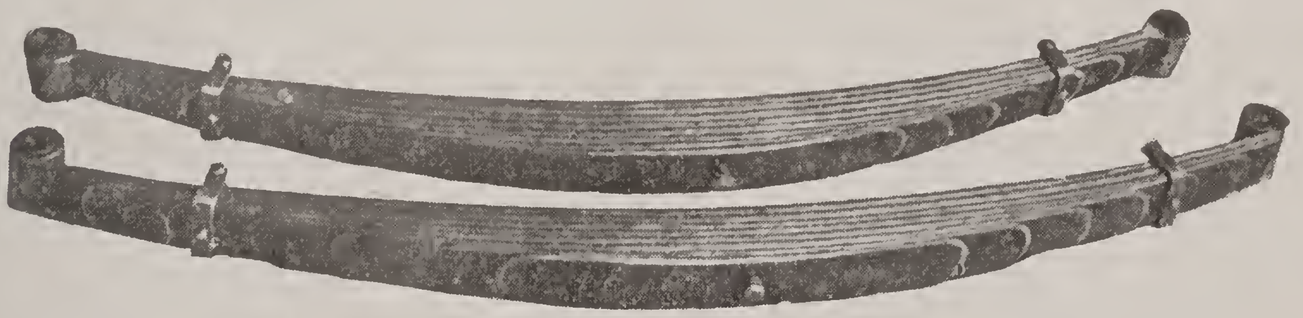


Fig. 411. Two Sets of Front-Axle Springs on Locomobile Cars

Electric Car Springs. The spring suspension of electric pleasure cars is similar to that of the gasoline vehicle, semi-elliptic suspension in front, and full-elliptic scroll-end suspension at the rear. The method of shackling is similar.

Varying Methods of Attaching Springs. Springs are attached in many ways. For example, the one shown in Fig. 398 might be shackled at the front end, fixed to the axle, and fixed to the center of the frame at the rear, the side and cross-springs being shackled together. Again, the front end might be fixed to the frame, Fig. 412, all other connections being unchanged. Or, with either method of fixing the front end, the spring might be swiveled on the axle, so as to be free to give sidewise without changing the other properties of the spring. Or, with either method of fixing the front end of the spring, and with or without the axle swivel, the cross-spring might be pivoted at the central point so as to be free to turn in any direction about this central point. This latter method prevents binding and unequal spring action when one side of the frame is unduly raised or depressed, the solid method of fixing the rear end resulting in a double action on the part of one spring, owing partly to the tilting of the body and partly to spring action itself. With the pivot joint, the spring first swings about this point until a position of equilibrium is established, when the suppleness of the spring comes into action, the result being a deflection of half what it would be in the other case.

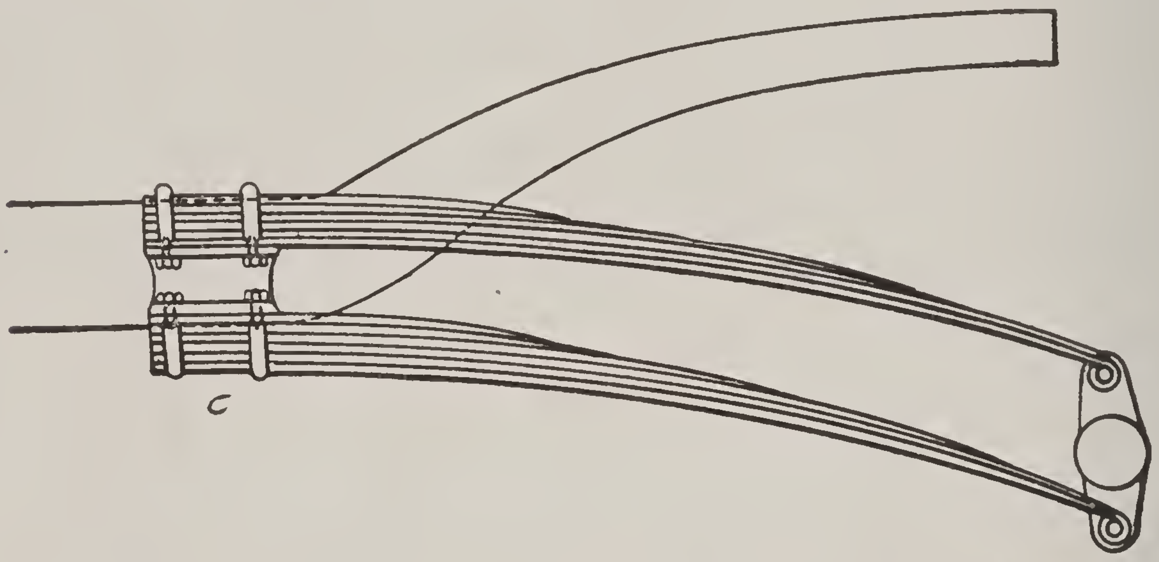


Fig. 412. Special Type of Double Quarter-Elliptic Rear Spring

This form of spring also is used with the spiral spring, the latter taking the place of the shackle between the side and rear members. In this position it serves two purposes: (1) as a connector, taking the place of and doing the work of a shackle, thus acting as a universal and swinging joint between the two springs; (2) as a shock absorber, taking up road shocks within its length, that is, in the coils, without transferring any of them to the body proper or, in case of heavier shocks, sharing with the side and rear springs. This, of course, is the true function of the springs—to allow the road wheels to pass over the inequalities, rising and falling as may be necessary, while the body travels along in a straight line, level and parallel with the general course of the road.

Underslinging. Almost any of the spring forms shown and described may be underslung, that is, attached to the axle from below. This is a quite common practice for semi-elliptic springs when used in the rear, but it is very uncommon for front springs. Similarly, full elliptics, whether having scroll ends or not, are frequently underslung. The three-quarter elliptic form when used in the rear is usually underslung; the platform spring is not underslung so often. The cantilever and quarter-elliptic springs have been mentioned in connection with the underneath attachment. It should be pointed out that the position beneath the axle lowers the center of gravity by an amount equal to the thickness of the spring plus the diameter of the axle plus twice the thickness of the attaching means, and this, too, without interfering with the quality or quantity of the spring action. In the case of the cantilever, the effect of underslinging is to reduce the straightness of the spring, that is, the form when attached above the axle is almost straight, while the form when fastened below the axle is very much curved—has considerable "opening".

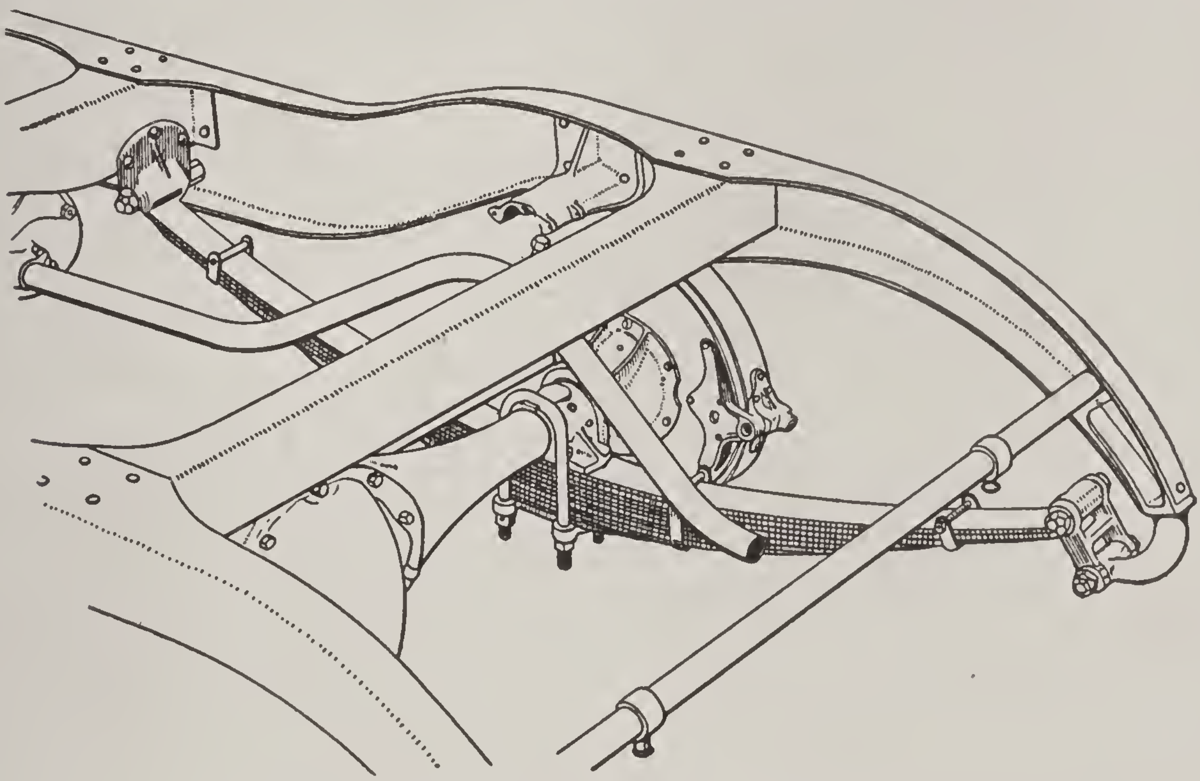


Fig. 413. Rear-Spring Arrangement on 1917 Premier

Shackles and Spring Horns. Considerable improvement has taken place in the method of shackling springs, and provision is now made with some types of springs for the adjustment of the shackles and hangers as well as for renewing bushings. Reference has been made to the tendency of design in rear-spring suspension and to the underslung types. Fig. 413 shows the design employed with the 1917 Premier, and, as may be noted, the springs are slightly diagonal, the front ends coming inside the frame line, while the rear ends are attached to goose necks of a rear extension of the frame pieces. Shackles are used for connecting the ends of the springs to the extensions.

A departure from the conventional shackle is the safety double shackle used on the Rainer 1000-pound capacity delivery car, shown in Fig. 414. In addition to the main eye on the main leaf of the rear spring, the second leaf is extended and formed into an elongated eye, allowance being made for deflection under load. The eye of the leaf is attached to the frame by the usual rigid spring bolt. Additional means of support are furnished by clamps on either side of the spring, one by a pin through the elongated eye, and the other by a pin through the lower end of the clamp which takes in the third and fourth leaves. It is pointed out that in case the main leaf breaks the eye of the second becomes the driving eye, and should this break, the spring will wedge between the under pin and the upper part of the clamp, thus obtaining rigidity which is essential with the Hotchkiss method of drive.

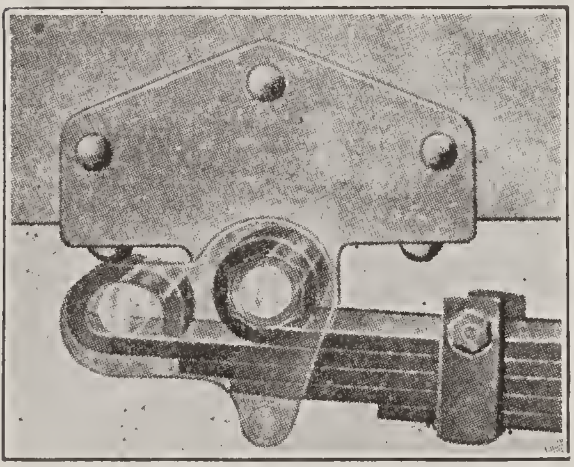


Fig. 414. Double Shackle Used on Rainer Delivery Car

Although the general practice is to shackle the semi-elliptic front spring at its rear, a departure which places the shackle at the spring horn or in front is noted in the Manly truck.

Adjusting Spring Hangers. The type of front-spring hanger, shown in Fig. 415, is adjustable. This adjustability is accomplished by relieving the body of the grease cup and screwing in the slotted bolt which eliminates side play. The grease cup body acts as a lock nut. The rear hanger of the front spring, Fig. 416, is adjusted by loosening the inside lock nut and the body of the grease cup. After removing the cap of the grease cup, the hanger bolt is turned out, or to the left, with a screwdriver, decreasing the distance between the links. The grease-cup body and lock nut are then set up tight.

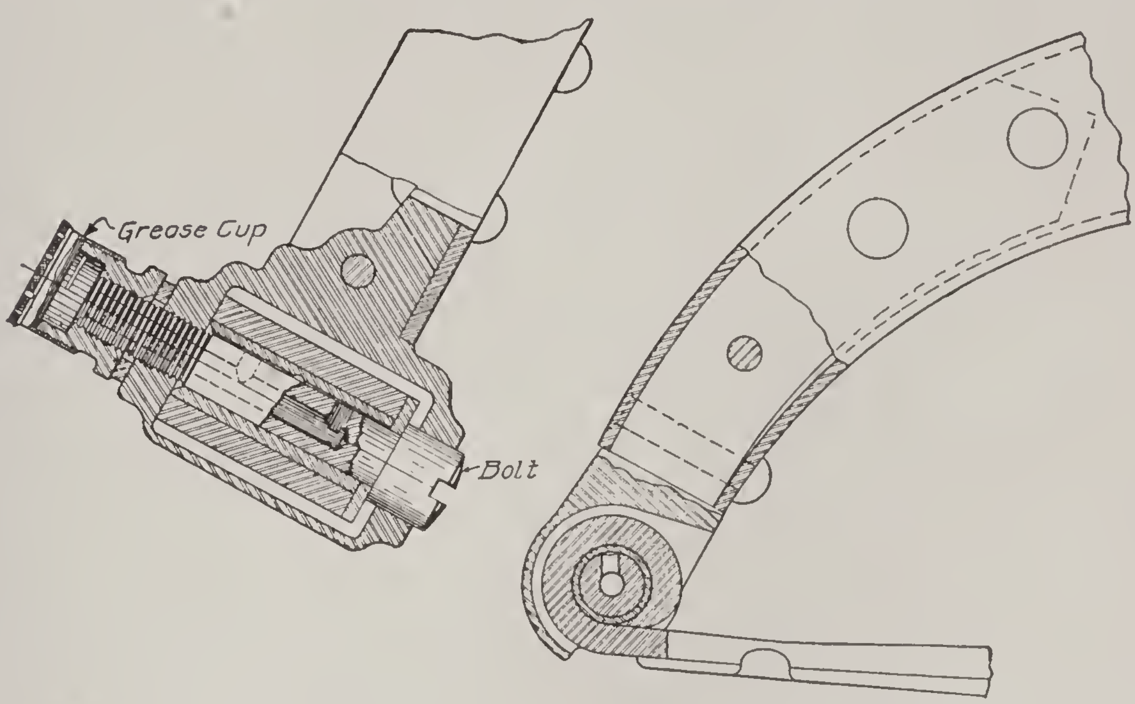


Fig. 415. Section of Adjustable Front-Spring Hanger

Provision is made with some types of rear springs for eliminating play when the rear ends are mounted on seats.

Spring Lubrication. All springs now are fairly well lubricated. All shackles are provided with grease cups, and other points of attachment to the frame are provided with oil holes. Where the springs are pivoted either on frame or axle, a big grease cup is usually furnished. In addition, it is now realized that the maker can prevent much of the noise formerly coming from dry and perhaps rusted steel spring plates working over each other. There are several ways in which oiling is accomplished. The springs are made with an internal lip, or groove, which is filled with lubricant when they are assembled; or between each pair of spring leaves is placed an insert having a series of oil pockets throughout its length, each filled with lubricant normally held in by means of a membrane cover; the movement of the spring plates and the heat generated thereby

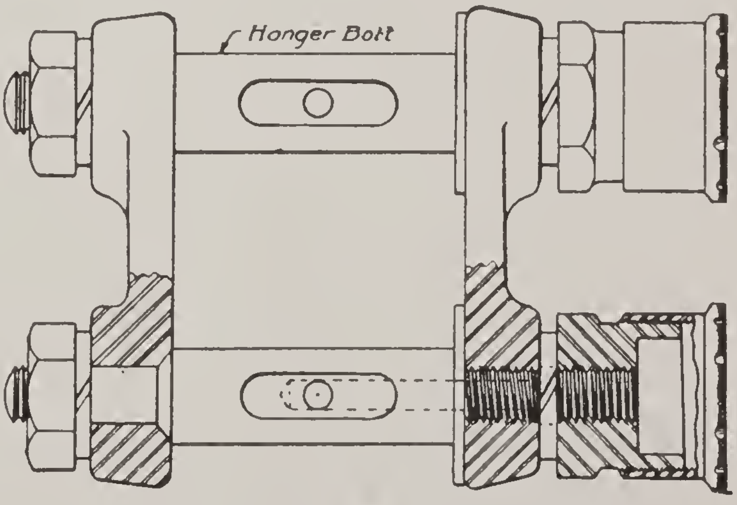


Fig. 416. Section of Rear-Spring Hanger

starts the lubricant flowing to all parts. An even later method is the attachment of external cups, provided with a wick which goes around the spring leaves and is pressed against their sides. The wick is kept wet with lubricant from the cups, and the motion of the spring leaves, together with the capillary action in the wick, draws the oil in between the leaves.

Spring Construction and Materials. A study of the illustrations used will show that practically all modern springs are clipped together, the number of these clips varying with the length of the spring and the use to which it will be subjected. Thus, Winton, Fig. 407, shows three clips and a band. Some springs show as many as five clips and two bands. But none indicate the use of spring ears—very small projections on the ends of the leaves—which are bent over the edge of the leaf next below it to assist in holding the spring together, but they are in quite general use. Altogether, there are about 14 or 15 forms of spring-leaf ends, but those in general use may be reduced to seven. These are: the oval; the round point; the short French point, a modification of the oval; the round end with slot and bead; the ribbed form, widely used on motor trucks; the square point tapered; and the diamond point.

In addition, sizes have been standardized in America to the extent that only five widths are used for pleasure cars and seven for motor trucks. Those for the former are: $1\frac{1}{2}$, $1\frac{3}{4}$, 2, $2\frac{1}{4}$, and $2\frac{1}{2}$ inches; for the latter: 2, $2\frac{1}{4}$, $2\frac{1}{2}$, 3, $3\frac{1}{2}$, 4, and $4\frac{1}{2}$ inches.

As the automobile business has called for better stand-up qualities under more severe conditions of use, the quality of steel used has been greatly improved, and other materials are better. The French make excellent springs, many of our best automobile manufacturers going abroad for their springs for this reason, but American springs are improving in quality so rapidly that this is becoming unnecessary. Formerly, all springs were of a plain carbon stock, but now a great deal of silicon, manganese, and vanadium steel are being used. Some chrome and chrome-nickel steel have also been tried.

SPRING TROUBLES AND REMEDIES

Usual Spring Troubles. *Lubrication.* The average repair man is likely to have more call to lubricate the leaves of a spring than any other one thing in connection with springs. True, they lose their temper; they sag and show signs of losing their set; plates break in the middle, at the bolt hole, and near the ends of the top plate; and inside plates break in odd places. But more frequently the springs make an annoying noise, a perceptible squeak, because the plates have become dry and need lubricating. When this happens, and the up or down movement of the car rubs the plates over each other, dry metal is forcibly drawn over other dry metal with which it is held in close contact; naturally, a noise occurs.

To lubricate the spring, it is well to construct a spring-leaf spreader. Of course, the job is best done by jacking up the frame, dismounting the spring entirely, taking it apart and greasing each side of each plate thoroughly with a good graphite grease, then reassembling it, and putting it back under the car. This is the best way, but it costs the most, and few people will have it done. Sometimes spring inserts are used; these are thin sheets of metal of the width and length of the spring plates, having holes filled with lubricant over which is a porous membrane.

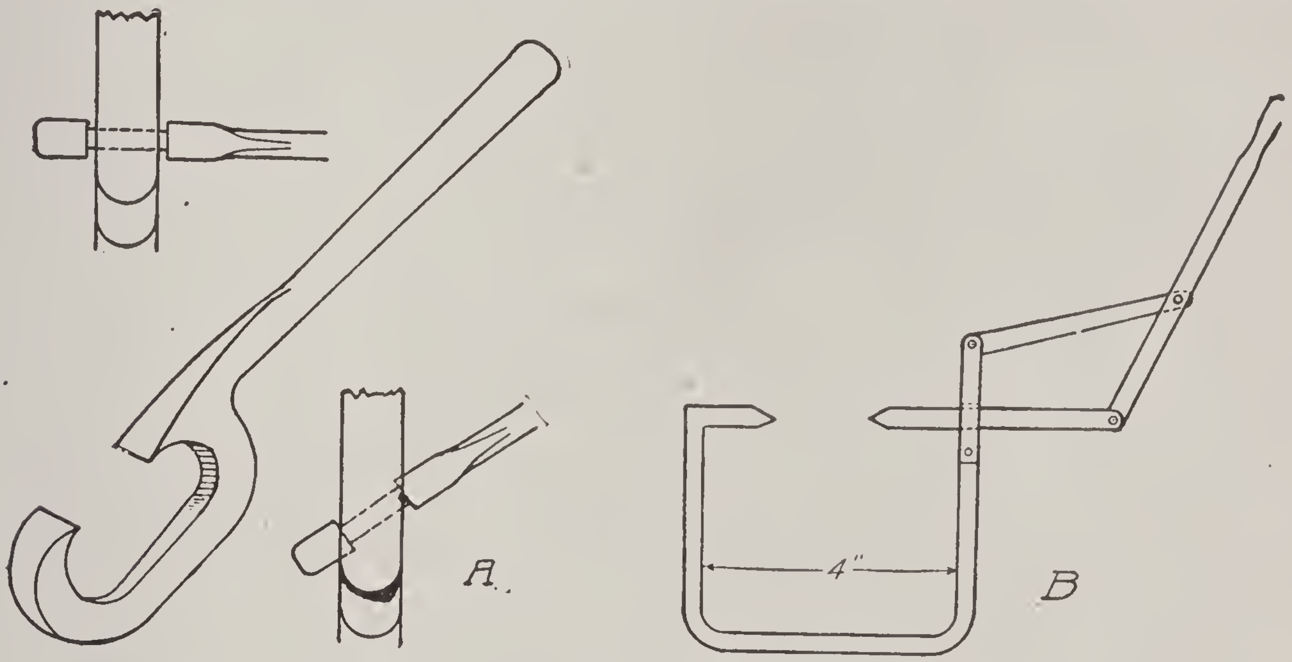


Fig. 417. Handy Tools for Spreading Spring Leaves to Insert Lubricant

For the ordinary spreading job, the plates must be pried apart and the grease inserted with a thin blade of steel, for instance, a long-bladed knife. To spread the leaves, jack up the frame so as to take off the load, then insert a thin point and force it between a pair of leaves. In Fig. 417, two forms of tools for making this forcible separation are shown. The first is a solid one-piece forging with the edges hardened. It is used by sliding the edges over the ends of the spring leaf, then giving it a twist to force it in between them, as shown in the figures. The second tool is intended to be forced between two plates by drawing back on the handle.

Tempering or Resetting Springs. When springs lose their temper or require resetting, it is better for the average repair man to take them to a spring maker. Tempering springs is a difficult job, as it requires more than ordinary knowledge of springs, their manufacture, hardening, annealing, etc. When springs are in this condition, they sag down under load and have no resiliency. If a great many springs are handled, a rack like that shown in Fig. 418 is well worth making.

Broken Springs. When springs break, there is but one shop remedy—a new plate or plates. But when they break on the road, it is necessary to get home. When the top plate breaks near the shackled end, repair this sufficiently to get home by using a flat wide bar with a hole in one end big enough to take the shackle bolt; bolt this bar to the spring in place of the end of the leaf which is broken.

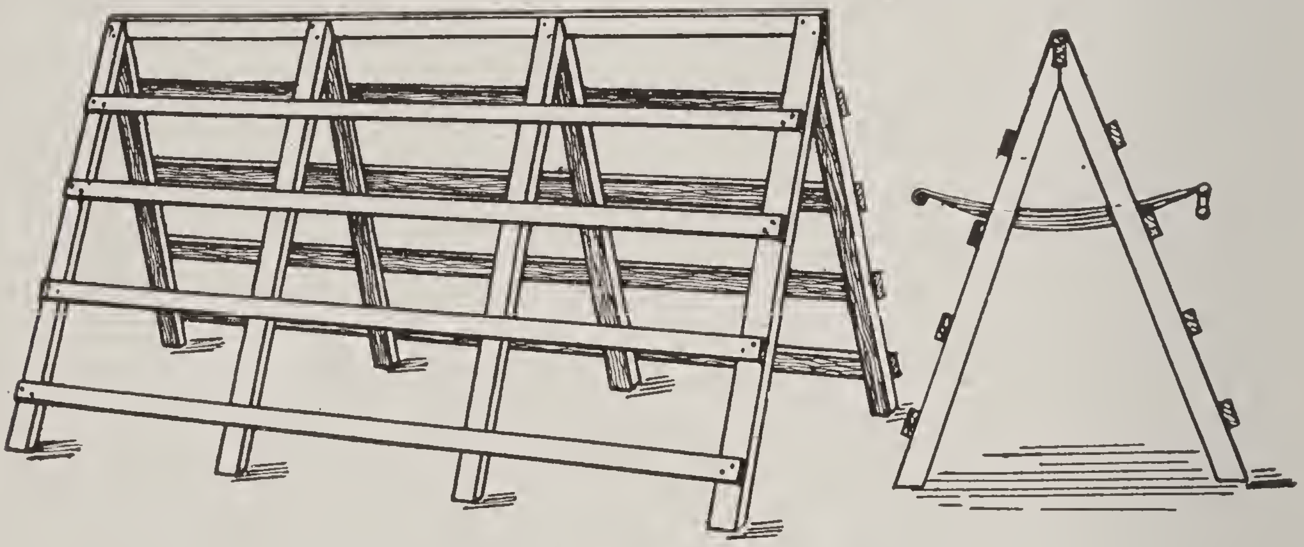


Fig. 418. Simple and Well-Designed Spring Rack

General Hints on Spring Repairs. As a rule, a break in a plate takes place where it does not prevent operating the vehicle, but it should be borne in mind that the damage to the plate subjects the other plates to extra work, and, unless the broken member be properly repaired or replaced, the others are likely to break. If one of the intermediate plates breaks in the center at the bolt, tighten the spring clips as much as possible. Very frequently the rebound clips will be found to be loose, and missing clips also contribute to spring breakage.

The removal of a plate from or addition to a set is very likely to upset the grading of the construction. It is not practical to replace a broken plate with a new one because it is of the same width and thickness, but an expert spring maker should be called in to see that the set, or fit, is correct. The fitting of a leaf requires the services of an expert spring man; while it appears to be a simple matter, the lack of knowledge by some claiming to be spring experts is responsible for breakage after the spring has been repaired. The spring clips and the nut of the center bolt should be kept tight. The importance of preventing the accumulation of rust on the leaves and of lubrication has been commented upon.

SHOCK ABSORBERS

Function. The ordinary flat-leaf springs of any of the types previously described are inadequate for automobile suspensions. When the springs are made sufficiently stiff to carry the load properly over the small inequalities of ordinary roads, they are too stiff to respond readily to the larger bumps. The result is a shock, or jounce, to the passengers. When the springs are made lighter and more flexible in order to minimize the larger shocks, the smaller ones have too large an influence, thus keeping the body and its passengers in motion all the time. These two contradictory conditions have created the field for the shock absorber.

The shock absorber is generally a form of auxiliary spring, the function of which is to absorb the larger shocks, leaving the main springs to carry the ordinary small recoils in the usual manner; in short, to lengthen the period of shock. This is done in a variety of ways, and, as might be expected, by a great variety of devices.

General Classes of Absorbers. The simplest forms of absorbers are the ordinary bumper, or buffer, of rubber and the simple endless belt, or strap, encircling the axle and some part of the frame and acting as the rubber pad does—simply as a buffer. There are the following classes of the more complicated shock-preventing and shock-absorbing devices: (1) frictional-plate or cam, in which the rotation of a pair of flat plates pressed together tightly—one attached to the frame, the other to the axle—opposes any quick movement of the two or of either one relative to the other; (2) a coil spring used alone and in combination—alone it is used in the plane of the coil, or at right angles to it, and parallel to the center line about which the coil is wound, while in combination it is found joined with the simple leather strap or with another coil spring of equal or sometimes of less strength, in the latter case the weaker one acting with the main springs; (3) the flat-leaf spring, a more simple description of which would be a small duplicate of the main semi-elliptic spring set on it so as to oppose its action; (4) the air cushion; and (5) the liquid device, in simple form and in combination with some one or more of the coil-spring forms.

Frictional-Plate Type. A frictional-plate type of shock absorber is shown in Fig. 419. This absorber consists of an upper arm attached to the frame, having at its outer end a frictional plate in contact with a similar plate at the upper and outer end of the other arm pivoted to the axle. The two plates are pressed together by means of the nut shown in the center; this nut is resisted by the spring beneath it and the slightly arched surfaces of the plates. When a sudden bump raises the axle, it must turn the two faces of metal across each other to the limit before it can lift the body. As will be seen, this means a considerable distance, and it can be made relatively greater by clamping the nut up tighter, thus increasing the friction between the surfaces, and, therefore, requiring greater force to turn them. Because of this adjustable quantity of friction, this type is called the governed friction type.

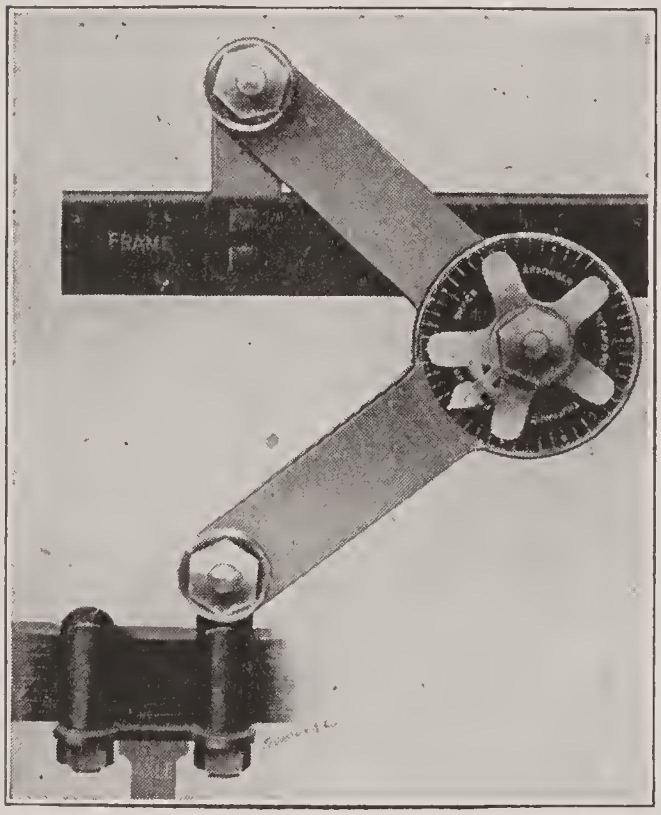


Fig. 419. Hartford Governed Friction Type of Shock Absorber
Courtesy of Hartford Suspension Company, Jersey City, New Jersey

When cams are used, practically the same result is obtained, except that the device is necessarily more complicated. The cam action usually generates some heat, and, for this reason, this form of shock absorber is most always enclosed, and the interior, where the cam works, is filled with grease or very heavy oil.

A modification of the plain frictional-plate form is seen in Fig. 420, which is called a passive range absorber, because, for ordinary movements of the springs to which it is attached, it does not come into action. When the usual spring action is exceeded, however, as in a sharp jounce, the device becomes effective. It appears much like the Hartford just shown, but the construction is decidedly different. The upper, or frame, arm is threaded to receive an Acme-threaded screw, which is carried by the lower, or axle, arm. The action of screwing this out tends to force the plate on the lower arm, which must move outward with the screw against a rubber washer held firmly by the outside nut and cover plate. Thus, the scissors action of the two arms on a sudden movement is resisted by the compression of the rubber washer. This compression can be increased or decreased by tightening or loosening the slotted outside nut, so that the screw is given less or more movement. The rubber washer is made with a series of holes in it to allow of compression.

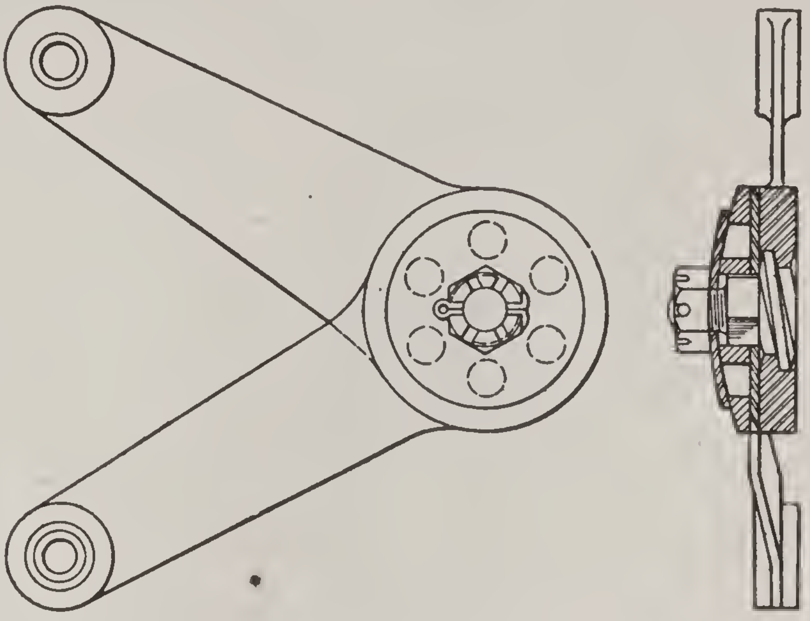


Fig. 420. Laporte Passive Range Friction Type of Shock Absorber
Courtesy of Charles Laporte, Detroit, Michigan

Coil Springs, Alone and in Combinations. *Springs Alone.* The coil-spring absorber is probably the most widely used form, primarily because it is both good and cheap; furthermore, it is simple and adds little weight. In most instances, the coil is so placed as to compress along the direction of its center line. One device, however, the Acme, shown in Fig. 421, works at right angles to this. It consists of a pair of coils, the two ends of each being so constructed as to go on the ends of the shackle bolts in place of the usual shackle. When the shackle is removed, one pair of ends is fastened to the spring in place of the shackle, while the other pair of ends is fixed to the frame

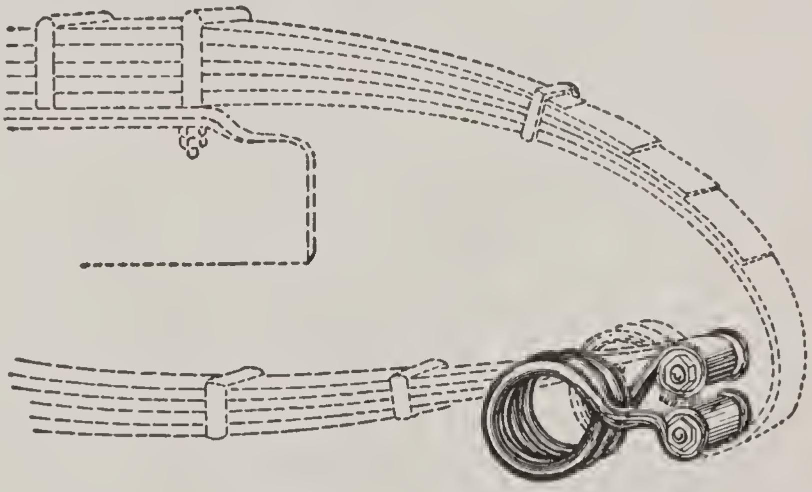


Fig. 421. Acme Torison Spring Fitted to Three-Quarter Elliptic Gears
Courtesy of Acme Torsion Spring Company, Boston, Massachusetts

or the other part of the spring, as the case may be. Note that this arrangement brings one of the coils on either side of the main spring end, extending away from it in a horizontal plane. In this position, the torsion spring acts as a spring shackle, absorbing the jounces and bounces so that they do not reach either the body, the attaching point, or the other half of the spring, as the case may be.

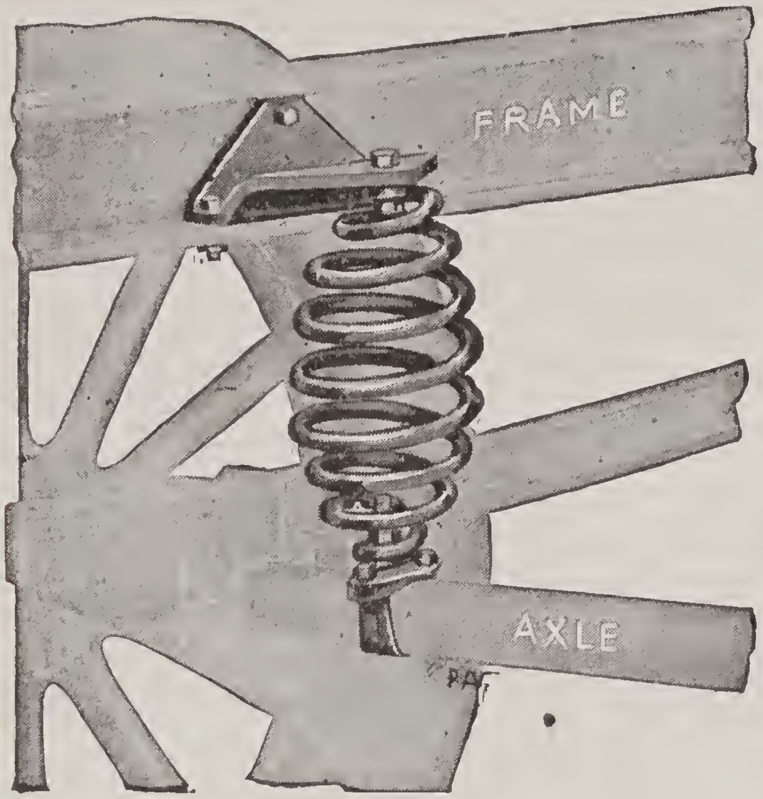


Fig. 422. Sager Equalizing Springs Are Very Simple in Construction
Courtesy of J. H. Sager Company, Rochester, New York

Fig. 422 is a simple coil spring of barrel shape, that is, the end coils are smaller than those in the center and are set between frame and axle in such a way that they absorb the jounces directly. This is probably the simplest possible shock-preventing device, consisting only of the spring and its top frame and bottom axle connections. These are made in four sizes of wire, varying from $\frac{5}{16}$ inch up to $\frac{13}{32}$ inch.

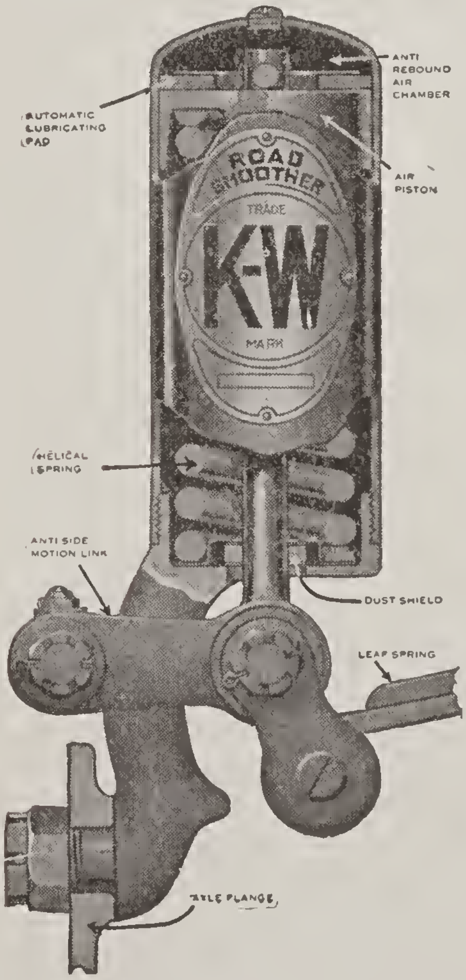


Fig. 423. K-W Spring Type of Road Smoother

In the K-W road smoother, shown in Fig. 423, the action of the spring is opposed by an air chamber at the top, creating a balance. A shock which causes the spring to move is opposed by the spring itself, while the rebound, or reaction, is opposed by the air compressed in the air chamber.

Combinations. Probably exceeded in simplicity only by the two forms just shown is the type in which a coil spring and leather band, or strap, are combined. One of these, the Hoover, is shown in Fig. 424. It will be seen that the spring end is fastened to the body, while the strap is attached to the lower end of the spring and encircles the axle. Hence, this will not interfere with upward movements of the axle, but only with the downward ones, that is, the axle is free to rise, but as soon as the car body starts to rise, the strap-spring combination acts to prevent it. This is particularly true if the axle has reached the limit of its motion and has started downward before the body starts upward. In that case, the body can move upward only the amount of slack in the strap plus the give of the spring, but minus the amount the axle has already moved downward. This inexpensive arrangement has found great favor on small cars.

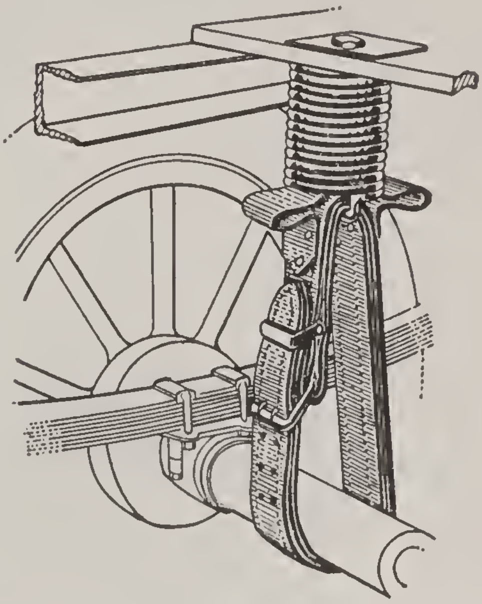


Fig. 424. Hoover Shock Absorber, a Spring and Strap Combination
Courtesy of H. W. Hoover Company, New Berlin, Ohio

Double-Coil Spring Types. In principle, the use of two springs is not different from the use of one. For structural reasons, however, it is easier to attach the two-spring form, while dividing the load up into two parts allows of the use of smaller diameters and smaller sizes of wire, thus making the device appear more compact. One of the two-spring forms, the J.H.S., is shown in Fig. 425. It consists of a pair of cylinders with coil springs within. The tops of the two cylinders are joined by a pin, and this joining pin is attached to the lower leaf of the spring. Inside the cylinders, pistons are set above each spring, and these are connected, this connection being used for the other half of the spring. At the bottom, the external bands on each of the two cylinders are connected, so as to keep them parallel at all times. Thus any movement upward of the lower part of the

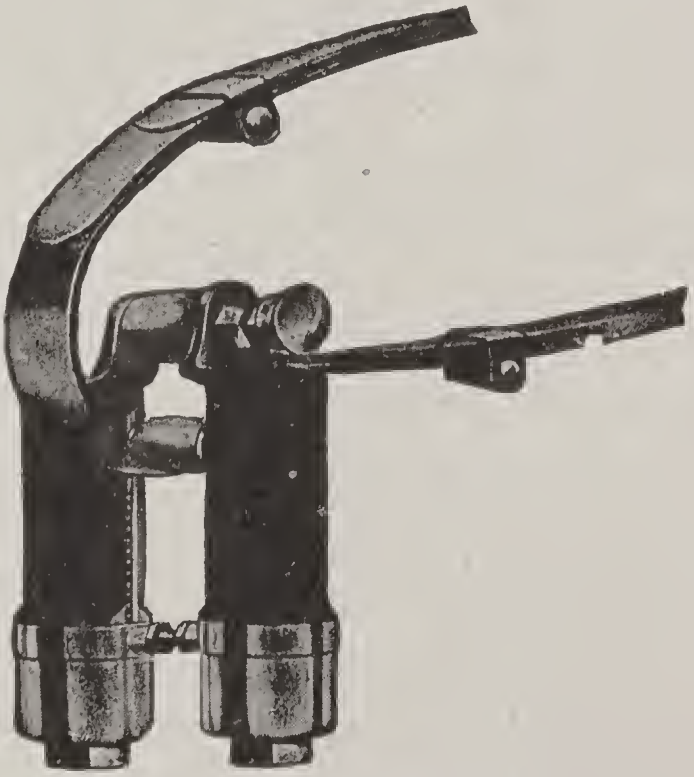


Fig. 425. J.H.S. Shock Absorber Has Twin Springs Encased

main-leaf spring tends to draw the enclosure for both shock-absorbing springs upward. The springs themselves resist this and absorb a large part of the movement both in force and distance.

Flat-Plate Recoil Springs. The third class, or flat-leaf spring, is a semi-elliptic unit in miniature. It is placed upon the top of the ordinary semi-elliptic spring, but it is reversed and has a spacing plate between the two. The object of this plate is to prevent recoil and to eliminate the rebound of the car body without restricting the flexibility of the main springs. As shown in Fig. 426, the Ames equalizing spring is constructed along these lines. As will be noted, this allows all downward movement of the spring, having no influence thereupon; but when the recoil, the upward equal and opposite reaction, comes, the smaller upper spring opposes this reaction and minimizes it, so that little or none of it reaches the body or the passengers.

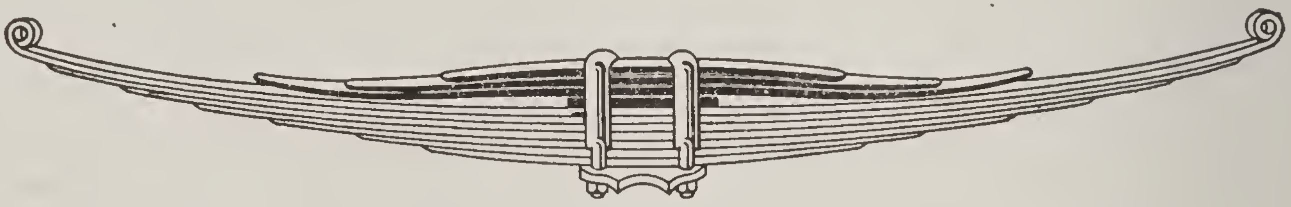


Fig. 426. Ames Equalizing Spring Is a Simple Small Inverted Semi-Elliptic
Courtesy of Clarence N. Peacock and Company, New York City

Air Cushion. Perhaps the most complicated form of shock absorber—certainly the most expensive and at the same time the most efficient—is the air cushion. This form consists of a pair of telescoping cylinders one being attached to the frame and the other to the spring. When road obstructions cause the spring to rise, it pushes its cylinder upward, but this movement is resisted by the air inside of the cylinders. With the amount of air properly proportioned to the size and weight of the car and its load, all this upward movement will be absorbed and none will reach the body and its occupants.

This rough outline describes the Westinghouse air spring, shown in cross-section in Fig. 427. In order to handle the air pressure and keep the cylinders within the commercial limits, oil also is used in the cylinders. This reduces the volume of contained air; but, for each inch the device is compressed, the air is reduced by a greater percentage of its original volume, consequently the resistance to compression is greater than it would be without the oil.

In the drawing, *A* is the upper section of the cushion chamber, telescoping into the lower section made up of tube *B* and crosshead *E*. The outer tube *C* is simply a guard. A steel casting *D* is bored out to form a guide for the outer tube and crosshead, and has a rectangular pad *F* machined for bolting the whole device to the bracket attached to the frame of the car. A shackle *G* is fastened to the end of the car spring *I* and is pivoted to the crosshead *E*. Packing ring *H* is used to make the inner cylinder a tight fit in the outer casing. A breather *J* is placed on the side, through which air is drawn by the upward movement of tube *B* through the medium of the tightness of packing ring *H*, just mentioned, and this air, on the downward movement, is forced through the passage *K* to a port partly surrounding the tube *B*. There is no packing ring between this tube and its guide *D*, so the air blows out and keeps the contacting surfaces clean. A further protection is afforded by the felt-wiper ring *L*,

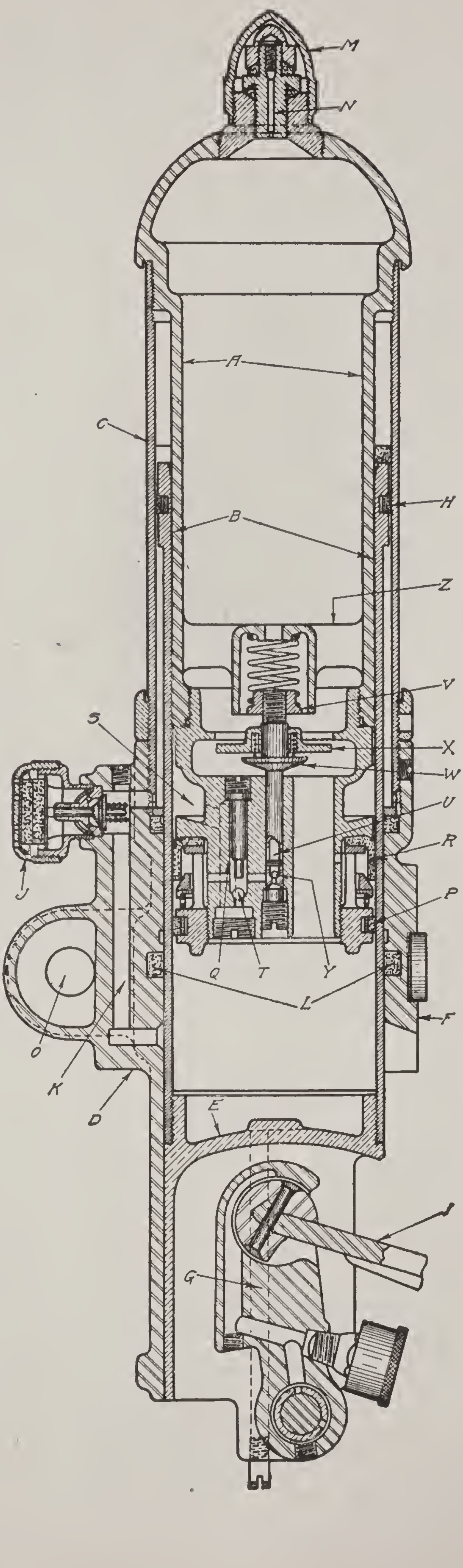


Fig. 427. Section through the Westinghouse Air Spring, Showing Construction and Operation
Courtesy of Westinghouse Air Spring Company, Pittsburgh, Pennsylvania

which retains the grease in the groove just above it. *O* is a rod connecting the two front or rear springs. At the top is the screw cap *M*, covering the air valve *N*, which is designed to be used just as the air valve in a tire.

The lower part of the device is filled with oil up to a level which approximates the line *Z*, all above this level being air under pressure. Consequently, the device actually compresses the air through the medium of the oil, which is incompressible. This oil forms a seal for the air chamber and prevents its leakage, although the oil itself is allowed to leak through, this leakage being pumped back automatically by the action of the springs. This works out as follows:

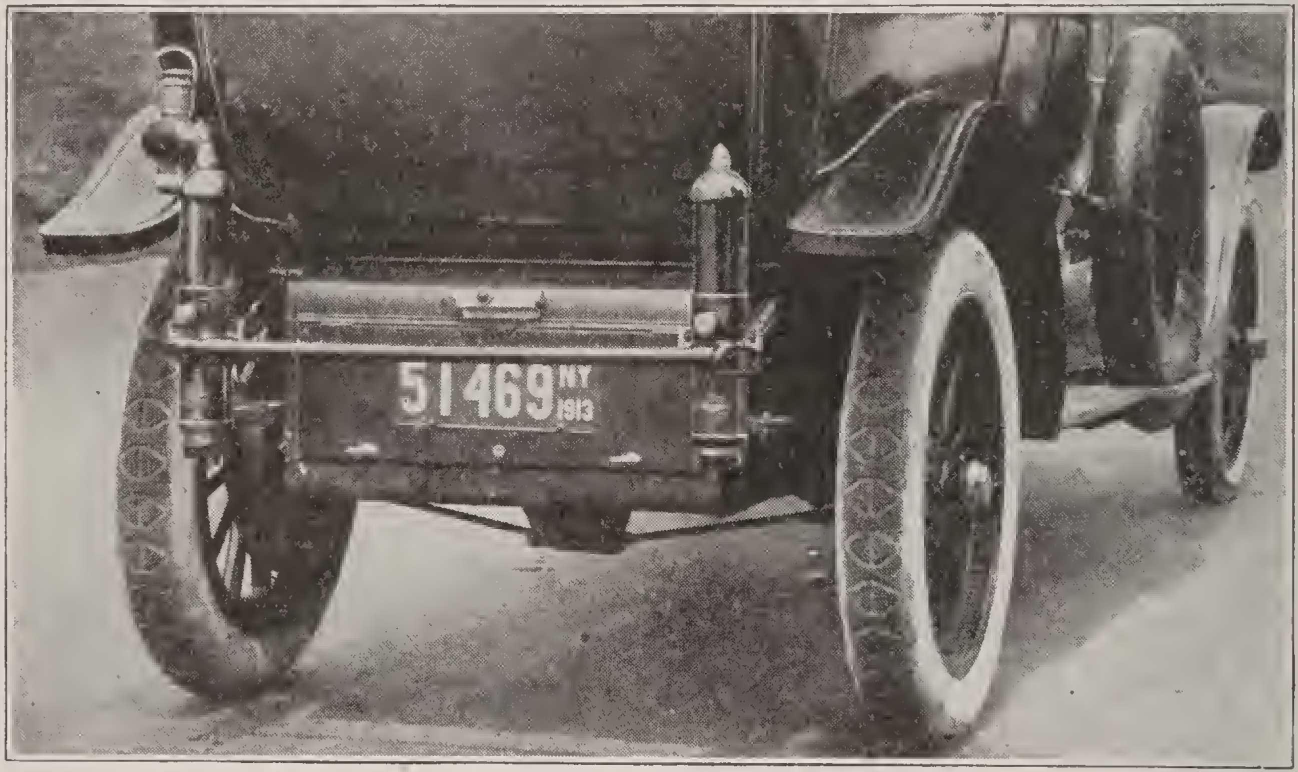


Fig. 428. Westinghouse Air Springs Applied to the Rear of Pierce Limousine

In what might be called the piston, although it is not, because it does not move—the other parts moving relative to it—there is the plain leather packing ring *P* and the cup leather *R* held out against the sides of the cylinder by the conical ring and spring.

The small amount of oil which does leak past the packing rings *P* and *R* is caught in the annular chamber *S*, whence it flows down through the vertical (dotted) passage *Q* into the chamber just below the ball valve *T*. In the center is a hollow plunger *U* of a single-acting pump. This has two collars on its upper end *V* and *W* and between them a disc *X*. This almost fills the passage just above it. The plunger is held down by the light spiral spring shown pressing on the collar *V*.

When a road obstruction is met and the spring rises, crosshead *E* rises and the upward movement of the oil takes the disc *X* upward until it strikes and carries with it collar *V*, which lifts the plunger and draws in a charge of oil. When the air compressed in the upper chamber of the device expands, and the car spring *I* and crosshead *E* go down again, the oil flows in the opposite direction, carries disc *X* down against collar *W*, and forces the plunger downward. Then the oil passes the ball check *Y*, goes through the hollow plunger, and is discharged back into the upper, or air, chamber. In the first place, the oil is put in by taking off cap *M* and taking out the air valve *N*. Then a special single-acting oil gun is used to force it in, a long nozzle being necessary to reach down into the interior, with a stop to limit this downward distance. The maker recommends that an excess be put in and then slowly drawn off to the right level.

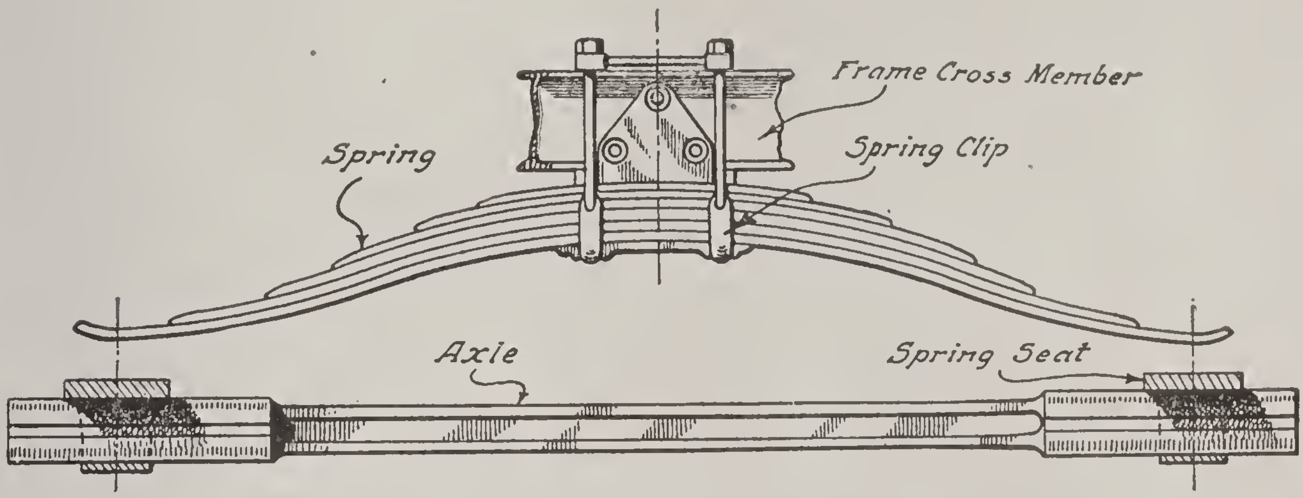


Fig. 429. Typical Semi-Elliptic Overload Spring

As will be seen from the foregoing, this device is essentially an air spring, and the air cushion does the work; but it is the oil below it, with its permissible leakage and with a pump to return this leaking oil, which makes this device practicable. To show the exterior, the part which most persons would see and remember, Fig. 428 is presented. This figure shows the rear end of a Pierce limousine equipped with a pair of the Westinghouse air springs. Note the breather, tie rod, cap at the top, cast guide at the bottom, and other parts previously shown and described.

Hydraulic Suspensions. The majority of the hydraulic devices developed as shock absorbers consist of turning vanes connected to the axle or spring, enclosed in a liquid-tight case filled with some heavy oil. There is a hole of small diameter in the case which connects the two sides of the vane, its motion forcing the fluid through this hole.

Thus the spring action simply pumps the oil from one side of the vane to the other and back again, the resistance to the flow of the liquid past the vanes and through the small hole absorbing all of the shocks.

Overload Springs. Overload springs are utilized with commercial vehicles and may be of either the leaf or coil type, and so arranged as to act only when the load on the main springs reaches a certain weight. The wear plate may be a separate platform, as shown in Fig. 429, or it may be formed integral with the pressure block. Where coil springs are used, they are made of square section, attached either to the frame cross-member or to the axle. Two such springs are used, one on each side. The design in Fig. 429 is a semi-elliptic. It is attached to a frame cross-member, and the ends are free so that they may make connection with a separate spring seat or a pad on the pressure block of the side spring when a predetermined load has been applied. With some trucks the front springs are mounted on a seat forged integral with the axle and are retained by box clips; a coil spring is attached to the pressure block, which acts as a bumper. Under excessive deflections these springs strike the bottom flange of the frame and arrest the rebound motion of the vehicle spring. The Jeffery Quad employs a spring bumper which is made of flat metal and is termed a volute spring. It is attached to a bracket fastened to the pressure block.

SUMMARY OF INSTRUCTIONS

STEERING

Q. Which wheel travels farther on curves and why?

A. The outer wheel must travel much farther on any curve, or turn, because it is turning through an equal angle on a curve of much longer radius. On very short turns, the distance the outer wheel must travel can be more than 50 per cent greater, or longer, than that of the inner.

Q. What general condition exists which makes the problem of steering so complicated to lay out?

A. The answer to the previous question gives an idea of the demands on the steering gear. The difference in the distances which the two wheels must travel on all curves—some differences being as high as 50 per cent, and with the difference shifting from one side to the other—is the general difficulty.

Q. How does the usual steering arrangement care for this?

A. By having the linkage which connects and steers the front wheels arranged so that a prolongation of the center lines of the two steering arms will pass through the center of the rear axle.

Q. How does this solve the difficulty?

A. When this arrangement is used, any swing or turn given to the steering system, say a turn to the right, will swing the left-hand knuckle through a larger angle than the right, although the two are connected together by linkage. This means that the inner, or left, wheel will swing about a shorter radius than the outer, or right, wheel, since if the two were turned through equal angles, the two radii would be equal.

Q. What other items complicate this steering problem?

A. The fact that the wheels themselves must toe in slightly at the front in order to steer easily and hold a straight line when set straight. Furthermore, the wheels must be set with their tops wider apart than their bottoms so that the line through the center of the plane of the wheel strikes the cambered, or raised, road surface at a right angle; this makes the whole situation even worse.

Q. Is the ordinary front axle of such a design that it gives perfect steering?

A. No. But it represents a working approximation which could not be improved upon without many needless complications. On a sharp turn, probably one wheel is dragged around the curve for a small portion of its length, but the distance is so small that it would never be noticed by the eye nor discovered in any difference of life in the tires.

Q. How is the turning of the steering knuckles about their pivots obtained?

A. The swinging movement of the steering knuckles is obtained through a fore-and-aft movement of the steering rod connected up to one of the steering-knuckle arms by a ball joint.

Q. How is this longitudinal movement of the steering rod obtained?

A. By a fore-and-aft swinging of the steering arm attached to the steering gear.

Q. How is this fore=and=aft movement of the steering arm produced?

A. By the partial rotation of the gear within the steering gear itself.

Q. And how is this partial rotation of the gear developed?

A. By the turning of the hand wheel, which turns the worm. The hand wheel is fastened to the upper end of the steering post proper (as distinguished by its stationary brass cover), while the worm is fixed to the lower end of it. Consequently, whenever the hand wheel is turned, the worm must turn also.

Q. Why are the worm and the gear used for steering gears?

A. The worm is used to secure irreversibility, as it is one of the few forms of mechanism which will not transmit power back through the entire group in the reverse direction, that is, it will not allow a movement of the wheels to be transmitted back to the steering wheel against the driver's wishes. In addition, it is compact, noiseless, easy to care for, wears little, and is highly efficient.

Q. What other forms of mechanism are used for steering gears?

A. Bevel gear, screw-and-nut, double screw, worm gear and full gear as distinguished from worm gear and partial gear, spur gear, simple bent lever, and other forms.

Q. What are the disadvantages of these forms?

A. With the exception of the worm and full gear, all are wholly or partially reversible, so if the front wheels strike an obstacle, the shock is transmitted back to the driver's hands.

Q. How are steering wheels made?

A. In various ways. Some are rings of glued-up wood, to the underside of which the arms of the steering-wheel spider are fastened. Others have the arms cast integral with the aluminum rim; still others are of bronze with a molded rubber surface applied to the bronze ring.

Q. Is the wood form, with spider fastened to it, popular?

A. It was, but it is rapidly going out in favor of something better. This construction is now used only on the cheapest cars and not on all of those.

Q. What are the advantages of the hinged, or folding, steering wheel?

A. Folding up the wheel out of the way allows the driver to get out on the lever side of the car, which might be practically impossible otherwise. It allows stout drivers more comfort in getting in and out. It is also an advantage when working in the front compartment of the car.

Q. What is the importance of the cross-rod at the front axle?

A. It is the only member tying the two steering knuckles together. If this rod is bent, the wheels cannot be steered accurately; if it is broken, they cannot be steered at all. In fact, the car cannot be moved forward when the rod is broken.

Q. Why is the rod usually placed behind the front axle?

A. As a protection against damage from high spots in the road. If it is back of the axle, it is well protected; but if the design places the rod in front of the axle, it has no protection, and trouble is likely to ensue on rough roads.

Q. Where is the front end of the steering rod carried?

A. As a similar means of protection, the steering rod is frequently carried over or above the front axle, so that the axle will protect it. Even when the design of axle, steering knuckle, and other parts necessitates this rod being below, it is placed as close as possible to the axle level, so as to get the maximum protection.

Q. What is the function of the steering knuckle?

A. It forms a pivot, or bearing, upon which the front wheel rotates; but, in addition, it forms the basis of steering, being capable of turning about a vertical (or nearly vertical) axis.

Questions for Home Study

1. Describe the complete steering mechanism of the Pierce-Arrow car.
2. Why is it better to steer with the front wheels than with the rear wheels?
3. Tell in detail how a worm and sector mechanism works.
4. Describe the working of a worm and nut device. Is it better than a worm and gear and if so, why?
5. How is the Gemmer steering gear adjusted (a) for wear of the worms; (b) for looseness of the steering wheel? How is it lubricated?
6. Describe the Hindley worm. What are its advantages; disadvantages?
7. Select and describe one form of steering-wheel construction.
8. How would you adjust a steering rod for (a) length; (b) wear?
9. Tell the advantages and disadvantages of the various possible positions for the cross-rod; for the steering rod.

FRONT AXLES

Q. What are the usual front=axle classes?

A. Eliminating freak forms, axles are generally divided into five classes: Elliott; inverted or reversed Elliott; Lemoine; front drive; and fixed axle, or fifth wheel, form.

Q. What is the nature of the Elliott front axle?

A. The Elliott form has the end of the axle in the form of a jaw, or Y, with a bearing above and one below the steering knuckle. The latter fits in between the two parts of the jaw, or Y, and consequently has a single central bearing.

Q. How does the inverted Elliott differ?

A. In the inverted, or reversed, Elliott form, the axle end is made with a single central bearing, while the knuckle takes the form of a jaw, or Y, and has the two bearings, one above and one below the axle end.

Q. Which of these two forms is the better?

A. There is little choice, but what there is seems to favor the Elliott form because it gives a stiffer and better bearing in the axle end, which is generally a good size rigid member. In fact, the axle ends can be made large enough in this form to have ball, roller, or other anti-friction bearings. This is not true with the reversed form.

Q. How is the Lemoine axle constructed?

A. The steering knuckle and its pivot are integral and form a letter **L**. The axle end is plain and forms a single bearing on the upper end of the steering pivot. In the regular Lemoine form, the **L** has its vertical leg extending upwards, and the axle is on top of the knuckle, so to speak. As constructed in United States the vertical leg of the **L** is turned downward, so that the axle is below the knuckle

Q. What are the advantages of this form of construction?

A. Both axle end and knuckle are simplified and can be constructed more cheaply. Moreover, the complete axle can be assembled or disassembled more readily and quickly. Some consider that this type has a nicer, cleaner appearance and thus improves the front of the car.

Q. What is the disadvantage of the Lemoine type?

A. The principal disadvantage of the Lemoine axle, ascom pared with other forms, is the difficulty of suitably handling the bearing loads. The ordinary axle has separate radial-load bearings and thrust washers or thrust bearings. In the Lemoine the axle-end bearing must handle both radial and thrust loads, as well as road shocks.

Q. What are the usual axle materials?

A. Modern practice restricts front axles to hand- and drop-forged steel, to tubular centers with forged ends, and to pressed steel. The latter is little used, however. Cast steel and manganese bronze as well as wood, have been used.

Q. What are the usual axle bearings?

A. Ball, roller, and plain bearings are widely used. For the sake of simplicity and compactness, the steering-pivot bearings are often plain, while the wheel bearings on the knuckle end are about evenly divided between ball and roller. Thrust bearings are about evenly divided between plain steel bearings with bronze washers, on the one hand, and with ball bearings, on the other.

Questions for Home Study

1. Describe a good method of truing front wheels.
2. How would you determine that front wheels were out of alignment?
3. Describe in detail the (a) Overland front-axle; (b) the Christie; (c) the Marmon.
4. How are axles lubricated, with reference to (a) wheel bearings; (b) steering pivots; (c) thrust washers or thrust bearings?
5. What are the disadvantages of cast front axles?
6. Are ball bearings better than roller bearings for front-axle pivots and if so, why?
7. Describe in detail the process of straightening a bent front axle. Would you use a template and if so, why?

FRAMES

Q. What is the need for a frame in an automobile?

A. Every automobile needs a frame, stiff and strong enough to support all the units for power development and use, down to the springs.

Q. Is there any radical difference between pleasure=car and motor=truck frames?

A. None, except that the truck frame must carry a much heavier load and, therefore, needs to be stiffer and stronger and that it must cost less relatively, thus necessitating a form or shape which is cheaper to construct.

Q. What materials are used for frames?

A. Principally steel and wood. Steel is divided into rolled, used mainly for trucks; and pressed, used for pleasure cars and for the smaller trucks, or delivery wagons. Wood is divided into plain straight wood, laminated wood, and wood used as a filler for steel.

Q. Is wood used at all widely?

A. No. With the exception of Franklin, using laminated wood, and of a few light cars and light trucks which have a wood filler inside of a pressed-steel frame, wood is used very little.

Q. Is steel tubing used for frames?

A. Frames are no longer constructed entirely of tubing, although this has been tried, but some designers use tubular cross-members for the support of the engine, the transmission, and other units.

Q. Is structural steel widely used?

A. For pleasure cars very little, if at all; for trucks quite freely, but in gradually decreasing quantity. Frame makers are producing better and cheaper frames of pressed steel each year, gradually eliminating any and all arguments in favor of rolled or structural steel.

Q. What is a frame "kick=up"?

A. When the rear end of a frame otherwise fairly straight and level is bent sharply upwards from two or three to as much as ten inches, beginning just forward of the rear axle and carried out to the rear end of the frame on this higher level, this whole raised rear end is called a kick-up.

Q. What is the purpose of a kick=up?

A. It lowers the central part of the chassis relatively, thus giving a lower step, incidentally lowering the center of gravity and making the car safer. It raises the rear end to give adequate rear springing.

Q. What is the shape of the modern frame, in plan?

A. It is gradually assuming a considerable taper. Originally, the frame formed a rectangle, with straight side members. Then it was found advantageous to narrow the front end to give more room for the front wheels to turn and thus allow a shorter turning radius. As this had the additional effect of shortening the engine-supporting arms, the makers were able to eliminate the sub-frame, with a saving of expense and weight. Finally, the width needed for modern touring car rear seats gradually widened out the rear ends of the frame, while the narrowing at the front became so great as to put a weak spot in the frame where its greater load had to be carried. It then became a logical step to make the frame taper from front to rear continuously, with straight sides. This is the form which all frames are assuming now.

Q. In what other ways do modern frames differ?

A. The rear cross-member is being eliminated very widely, as is also the front cross-member, so the triangular-shaped frame is not closed at either end. Formerly, the depth of the frame was pretty much the same from front to rear, but now this tapers very materially from the front up to the middle and then down again at the rear. A good stiff typical frame would be perhaps $2\frac{1}{2}$ inches to 3 inches deep at the front, 6 inches deep in the middle, and perhaps $2\frac{1}{4}$ inches to $2\frac{3}{4}$ inches deep at the rear. In short, except for perhaps 20 to 24 inches of length right in the middle, the frame depth would differ continuously.

Q. What is the advantage of varying the depth so much?

A. It eliminates every pound of excess weight, putting much metal where there is heavy load and severe stresses and little metal where the load and the stresses are light.

Q. Is this form of construction more expensive?

A. No. The art of pressing the frame out of sheet steel has been developed through large quantity production to such an extent that a frame of this type, with a constantly varying depth, costs no more than a straight frame cost four years ago.

Q. Does this form give the repair man more to do?

A. No. On the contrary, frames give less trouble in the way of sagging, breaking, or cracking than ever before. The frame troubles of today are mainly due to poor or light design, in an effort to lower weight too far, or to accidents.

Q. What has been the effect of cantilever springs on frames?

A. One effect of cantilever springs for rear use has been to eliminate the rear cross-member, as spoken of previously. Another effect has been to continue the deepest section back quite a few inches to the point of support of the front end of the cantilever.

Q. Is the trussed, or latticed, frame widely used?

A. No. Only by one or two makers, although a few heavy cars have a truss rod below the main frame to add stiffness and strength. The trussed, or latticed, frame is a new departure in frame design.

Q. What are the noticeable tendencies in frame construction, other than those already mentioned?

A. The use of heavier frames, that is, heavier sections of metal, deeper side members, and general stiffening is being accomplished without much gain in weight, owing to the better distribution of the metal. The combination of other units, as steps, step supports, and fenders with the frame is being worked out, this being one of the tendencies in construction. The general carrying of spare tires at the rear is having an influence, but there seems quite a tendency to construct the body so as to enclose the tires, which, if carried out, would change this.

Questions for Home Study

1. How would you repair a sagged frame, if sagged at (a) front end; (b) center; (c) rear end; (d) cross-member?
2. Describe the method of welding a cracked frame by the oxy-acetylene process.
3. Describe the following frames in detail: (a) Stearns-Knight; (b) Marmon; (c) Fergus.
4. How is the Franklin wood frame built up?
5. How is what is called an "armored frame" made?
6. Tell how to remove and replace an underpan.
7. What material is usually used (a) for a truck frame; (b) for a light pleasure car; (c) for a heavy touring car?
8. Give the advantages and disadvantages of pressed steel for frames.

SPRINGS AND SHOCK ABSORBERS

Q. What is the need for vehicle springs?

A. To support the load in a flexible manner so that the jolts and jars of the road will not be transmitted to the passengers or load. In addition, a flexible connection between the power plant and the road wheels is needed.

Q. How many recognized different types of spring are in use?

A. Seven; all of which are made and used in all sizes and qualities for all kinds of load.

Q. What are these seven types?

A. The semi-elliptic, the full elliptic, the three-quarter elliptic, the platform, the cantilever, the quarter elliptic (or half semi-elliptic, as it is sometimes called), and the coil. All but the last three also are made with scroll ends, which alters the general appearance without altering the type of action.

Q. What is the shape of the semi-elliptic?

A. This form has a slight bow upwards, the two ends being slightly higher than the middle. The middle is attached to the axle and the ends to the frame, and when load is applied, these ends come down, flattening the spring so that it approaches a straight line.

Q. Describe the full-elliptic spring.

A. This form has the shape of two semi-elliptics, one inverted and set on top of the other. This gives it the appearance of an elongated letter **O** with points at the ends. The lower half is attached to the axle and the upper half to the frame, and loading tends to bring the two halves closer together, flattening the **O** still farther.

Q. What is the form of the three-quarter elliptic spring?

A. This consists of a flat lower semi-elliptic member and a highly curved quarter-elliptic upper member, the two being joined by means of a shackle. With the exception of the difference in curvature of the two parts and the use of the shackle to join them, this has the appearance of a full elliptic with the upper forward quarter cut away. When loaded, both members give slightly, the upper quarter more than the lower half. The shackle gives a considerable difference in this action from that of the full-elliptic.

Q. What is the platform spring like?

A. This spring consists of three semi-elliptics joined together at the ends so as to form three sides of a rectangle. The two sides are fastened, respectively, to the axle at the middle of each, to the frame at their front ends, and to the third spring at the rear ends. The rear spring is inverted and its center is fastened to the center of the rear end of the frame, while its ends are shackled to the rear ends of the two side springs. This makes a combination in which the normal semi-elliptic spring action is modified somewhat by the inversion of the rear cross-member and by the use of shackles at the ends of all three. While popular three or four years ago, it is now going out in favor of the three-quarter elliptic.

Q. What is the cantilever spring like?

A. It consists of an inverted semi-elliptic fixed or shackled to the outside of the frame at the front end, hinged or pivoted slightly forward of its center to the outside of the frame, and having its rear end attached to the upper or lower surface of the rear axle. It is used in greater lengths than any other form of spring and is very popular.

It is the most simple spring now in use and is said to give the easier riding of all.

Q. What is the quarter-elliptic spring like?

A. This is simply what its name indicates, one-half of a semi-elliptic or one-quarter of a full-elliptic. Its front end is fixed to the frame outside, and the rear end is shackled or allowed to slide on the rear axle. It is generally inverted. In reality, it is a cheap substitute for the cantilever or inverted semi-elliptic, this use being allowable because of the light weight of both car and load.

Q. Is this used in any different way?

A. Sometimes a pair of these is used, one above the other, with the idea of doubling the resistance or rather of giving equal resilience with but half the movement.

Q. What is meant by underslinging?

A. When this refers to frame, the entire frame is placed below the springs. This has gone out of use. When referring to springs, this means placing the spring below its support, as below the rear axle. This construction lowers the frame and center of gravity by the thickness of the spring plus its seat plus the diameter of the rear axle, sometimes amounting to a total of five inches. It is growing rapidly in popularity.

Q. What is the purpose of a shock absorber?

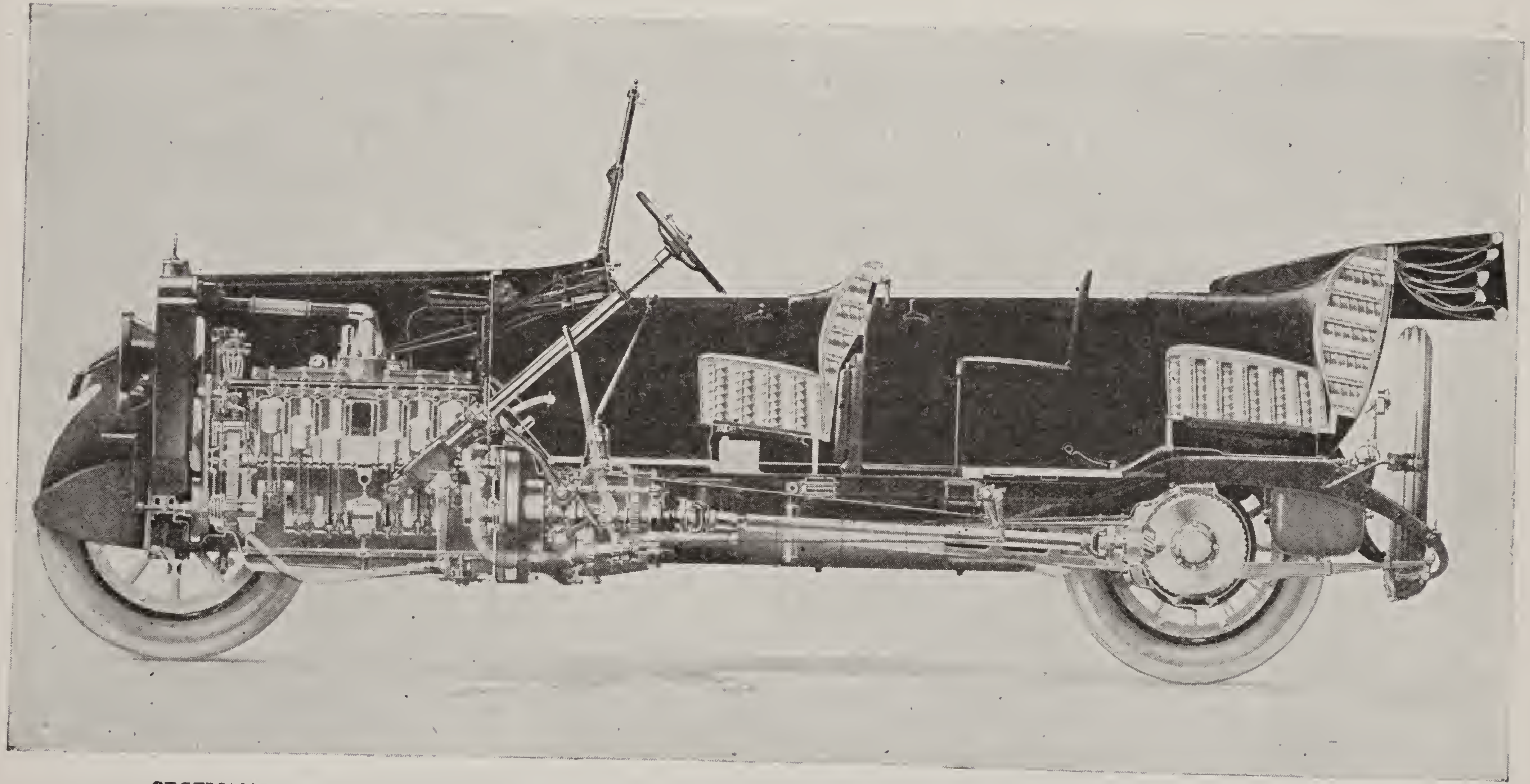
A. To absorb the small vibrations while the spring cares for the large ones. It generally takes the form of any auxiliary spring or friction device.

Q. What are the general classes of shock absorber?

A. Coil spring, flat-plate spring, friction plates, compressed air, and a few hydraulic (or liquid) forms.

Questions for Home Study

1. How are springs lubricated (a) as to leaves; (b) as to shackles?
2. How are the spring leaves separated for lubrication?
3. Describe a method of getting home with a broken rear spring.
4. Why do racing cars have their springs wound with rope or cloth?
5. Describe the following car springs in detail: King; Winton; Ford.
6. How do electric car springs differ from those of gasoline cars?
7. What are the standard spring-plate widths?



SECTIONAL VIEW OF PACKARD "TWIN SIX", SHOWING POWER UNIT AND TRANSMISSION TO REAR AXLE

Courtesy of Packard Motor Car Company, Detroit, Michigan

GASOLINE AUTOMOBILES

PART VI

FINAL-DRIVE GROUP

REAR AXLES

TRANSMISSION

Units in the Final Drive. Generally speaking, the transmission is located in the middle or forward end of the chassis. When this is the case, the final drive begins right at the rear end of the transmission. The units back of the transmission, then, would be a universal joint; a driving shaft; possibly another universal joint; the final gear reduction; rear-axle shafts and enclosure; the differential; the torque rod, or tube, or substitute for it; the wheels; the brakes; the tires; and other smaller units.

Even when the transmission is placed on the rear axle, this general layout is changed little, and the transmission, which has been covered in detail previously, is not considered again. In the case of a chain drive, which is still used on one pleasure car or perhaps two, on a number of small trucks, and on a large number of large trucks, this layout is changed considerably. In the large trucks, the transmission in perhaps 90 per cent of all cases would be in a unit with the jackshaft, which means that for consideration in the final-drive group there would be only the driving shaft to the transmission; the joint or joints in it, if any; the chains and the method of adjusting them; the rear axle and wheels; the brakes; the differential, of necessity becoming a part of the transmission; and the jackshafts.

To make this clear and point out the various units, it will be noted in Fig. 430 that it is a unit power plant. Directly back of the transmission is the first universal joint, driving through the hollow propeller shaft to the rear axle, in front of which is the second universal joint. The rear-axle group includes the axle shafts, differential gears, final gear reduction, gear housing, and the wheels. The torque reaction of the drive, to be explained later, is taken by the torque rod, marked in the drawing, which connects the rear axle to the under

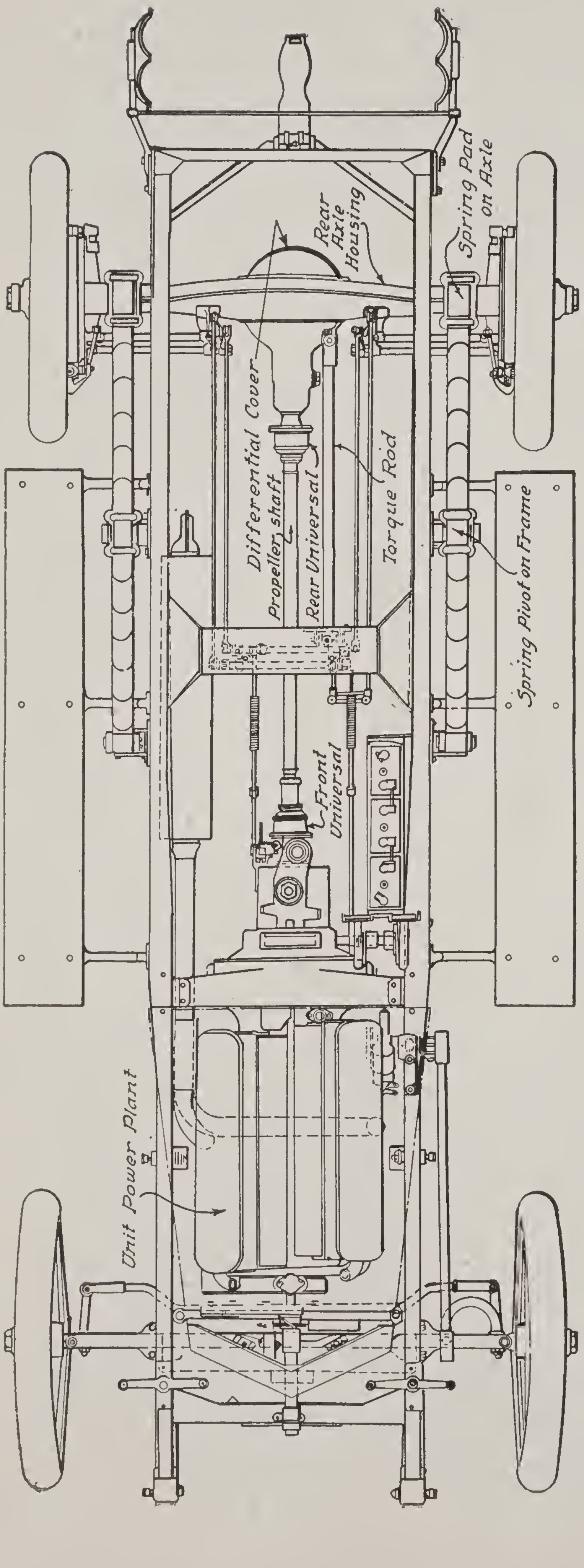


Fig. 430. Layout of Units in Final-Drive Group
Courtesy of Federated Motors Company, Indianapolis, Indiana

side of the stout frame cross-member in front of the axle.

Universal Joints. The purpose of taking up the universal joints—it can be seen from the drawing—is to show how the rear axle rises and falls or moves sidewise in either direction without making any difference in the transmission of power to the axle. When joints are used at other points, the purpose is generally to take care of any lack of alignment, but here the purpose is to transmit power at an angle.

The transmission of power at an angle is effected by constructing the joint so that it can work at any angle. Usually, this is done by constructing the central member in the shape of a cross, with four projecting arms or pins, all in the same plane. The ends of the two shafts are made in the form of forks, or Y's, and are set at right angles to each other, that is, the forks are laid in planes which are at right angles. The fork on one shaft is fastened to a pair of diametrically opposite pins, while the fork on the other shaft is fastened to the other pair of diametrically opposite pins. Each shaft is able to turn on its pins about a line through the center of both. As these two lines are in planes which are at right angles to one another, but intersect at a common center, movement is possible in either plane, or by combination movements of both, in any direction.

Slip Joints. In many situations, a real universal joint is not needed, since the parts are not actually free to move in all directions; but what is needed is slight freedom up and down or sidewise combined with possible fore-and-aft movement. In such cases a slip is used, the name giving the idea of a joint which allows one shaft to slip, or slide, inside the other. The general construction of slip joints varies. Sometimes a round gear is fastened to the end of one shaft; this gear has a fairly large diameter and many teeth, with the teeth chamfered to an unusual extent—almost rounded, in fact. An internal gear of the same size and number of teeth with similarly rounded profiles is meshed with the hollow gear of the other shaft. Both gears have unusually wide faces. This combination gives an action that is almost universal, and also allows lateral sliding of perhaps ½ inch.

The second form of slip joint consists of a squared shaft and square enclosure. The end of the shaft has a member split along a central line attached to it; the exterior approximates a round of large diameter, but the interior is machined to a perfect square, one-half in each part of the split member. Attached to the end of the other shaft is a member machined to an exact square, but slightly rounded in a fore-and-aft direction. The square will drive, no matter in what part of the housing it is located, so that considerable fore-and-aft sliding is possible. In addition, the rounded surface of the square gives an approximate universal effect. The split housing is used to make assembling and disassembling easier and much quicker. Sometimes such a housing is put on the end of each shaft, the connecting member being made in the form of a dumb bell, but with two square ends—one to work in each squared-out housing. In this way the effect of a full universal joint with the fore-and-aft sliding is obtained at less cost, and with easier assembling and disassembling as extra advantages.

Occasionally a square joint is constructed as simple and small as possible, in which case the housing is not split and the shaft end is not rounded. This gives a simple square which drives through a simple squared-out hole. In this case there is no universal action, but simply lateral or sliding freedom.

Other Flexible Joints. To get away from the complication of the universal joint and yet give practically the same results, many other forms have been produced. A very thin disc of tempered steel, with the two shafts bolted to the two opposite sides of it, has been used. The metal will bend and give enough to allow considerable angle of drive. Later forms of the same joint use leather in several thicknesses, the leather being bolted up to the two shafts in the same way. A joint of this kind, consisting of several layers of fabric which have been fastened together in laminations until a disc of fair thickness, say $\frac{1}{2}$ to $\frac{3}{4}$ inch, has been built up, is shown in Fig. 431. Then the leather is cut round and drilled for the bolts. In this form, six bolts is the preferred number, three for each shaft end; they are in a three-armed spider fastened to the end of each shaft, as the figure shows. These newer forms are usually convenient for the repair man, for they allow breaking into the main shaft by the simple removal of the three bolts (or two as the case may be). By taking out the bolts at each end of such a shaft, the shaft itself can be removed, leaving the other units in the chassis ready for immediate removal, according to the needs of the repair job.

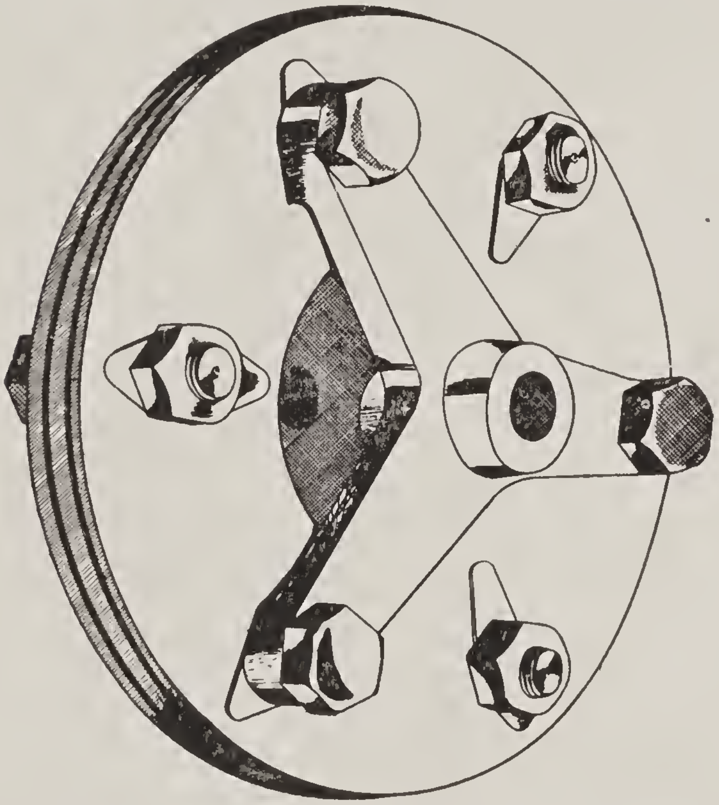


Fig. 431. Laminated Discs Forming Flexible Shaft Coupling
Courtesy of Thermoid Rubber Company, Trenton, New Jersey

Types. Possible types of final drive, from the gear box to the rear axle and the driving wheels or from the motor to the gear box—in case this is mounted on the rear axle, as is not uncommon practice—are practically limited, in cars of sound design, to shaft and double-chain constructions.

Shaft Drive. In its usual form, shaft driving in an automobile involves simply a propeller shaft interposed between the rear axle and a revolving shaft in the car above the spring action. There is some provision for taking the torque of the shaft and of the axle so that they shall maintain their proper relative positions.

In Fig. 432, a typical short driving shaft with its two universal joints is shown. This is such a shaft as would be used in the car shown in Fig. 430, except that the latter is a long wheel-base car with its transmission in a unit with the motor and clutch and thus, far forward. This combination necessitates a very long propeller shaft. The one shown is actually from a car having a short wheel base, with the transmission located amidships. This is a combination which calls for a fairly short propeller shaft.

The short shaft, shown in the figure, is a solid shaft. The modern tendency toward lighter weights is being worked out in the case of propeller shafts, and many are now made hollow. By making the diameter slightly larger and having a large central hole, unusually light weight is obtained with all the strength of the solid form. In addition, the larger diameter hollow shaft has more rigidity than the small diameter solid form, and in many of the modern cars without torque or radius rods, unusual rigidity of the driving shaft is necessary. Other forms have been used for the driving shaft, but they come more or less in the freak class. About two years ago, a car was brought out with a spring, or flexible, shaft, which consisted of a rectangular member of considerable height, but fairly thin. The idea was not only to transmit the power of the engine, but to do it in a flexible manner, that is, the shaft was supposed to absorb all the sudden changes, such as quick acceleration or quick braking. At the same time, one of the electric-car makers brought out a chassis with a square driving shaft of very small size. This served the same purpose as the flexible

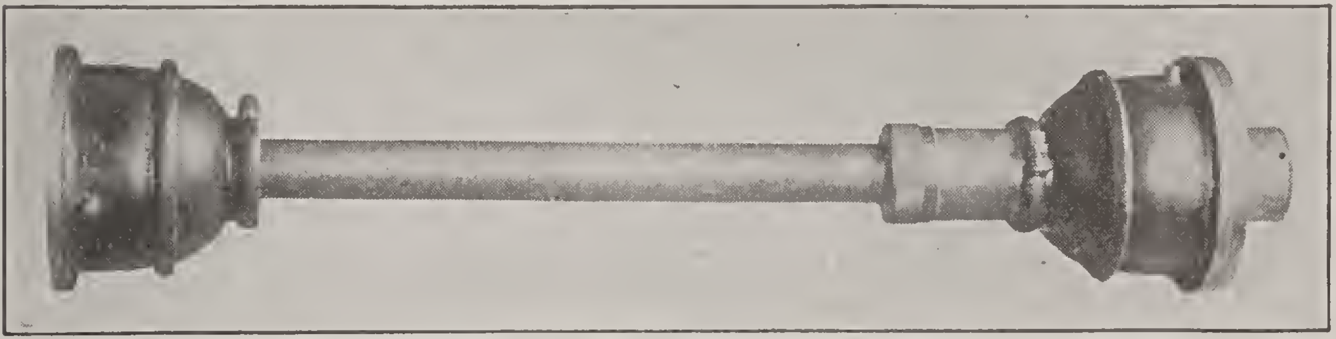


Fig. 432. Ordinary Driving Shaft of Solid Form with Two Universal Joints

shaft only in a different way; its two ends, setting in square holes, formed two sliding joints without further machining.

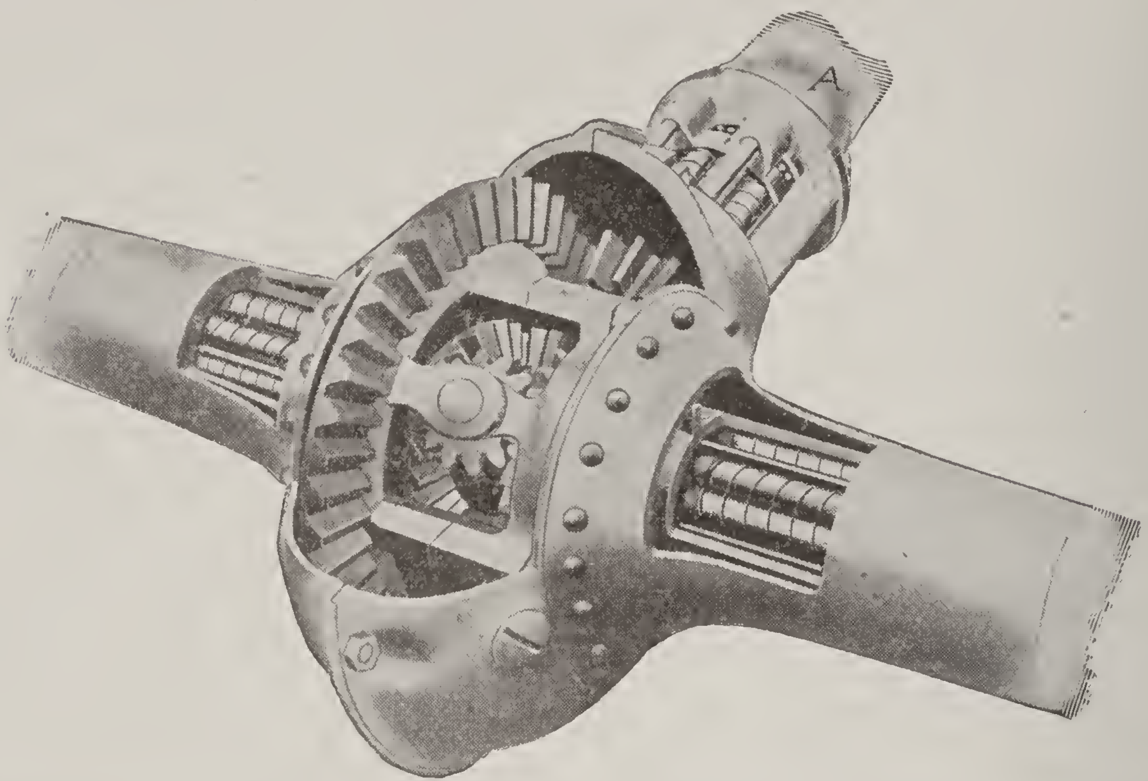


Fig. 433. Ford Final Drive, Differential, and Axles

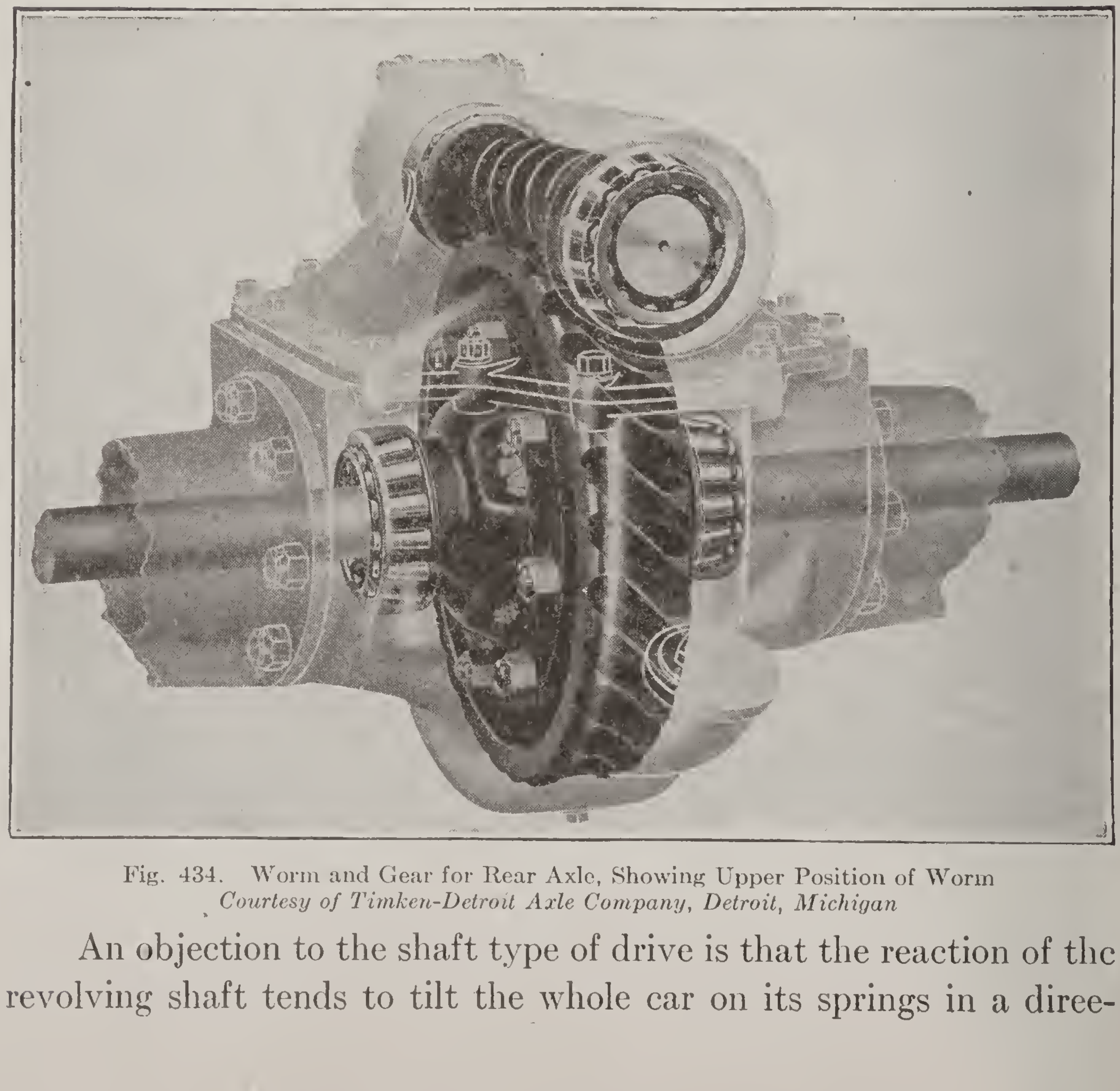


Fig. 434. Worm and Gear for Rear Axle, Showing Upper Position of Worm
Courtesy of Timken-Detroit Axle Company, Detroit, Michigan

An objection to the shaft type of drive is that the reaction of the revolving shaft tends to tilt the whole car on its springs in a direction opposite to that in which the shaft is turning. In some cars, this is counteracted by the use of slightly heavier springs on one side. The advantages of the shaft drive are the complete enclosure of all working elements, with their consequent protection from dirt and the assurance of their proper lubrication.

The final drive of the Ford automobile, in which the end of the propeller shaft is shown at A, together with the bearings in which it revolves, the pinion by which it drives the car, the axle, the differential, and the bearings of the floating inner elements of the axle is illustrated in Fig. 433.

The shaft drive does not necessarily include the use of bevel gears for the final reduction at the rear axle; in fact, almost any form of gears may be used. In one well-known shaft-driven commercial car, the final gears consist of a pair of plain spur gears, while on the shaft of the second of these gears is a pair of bevels.

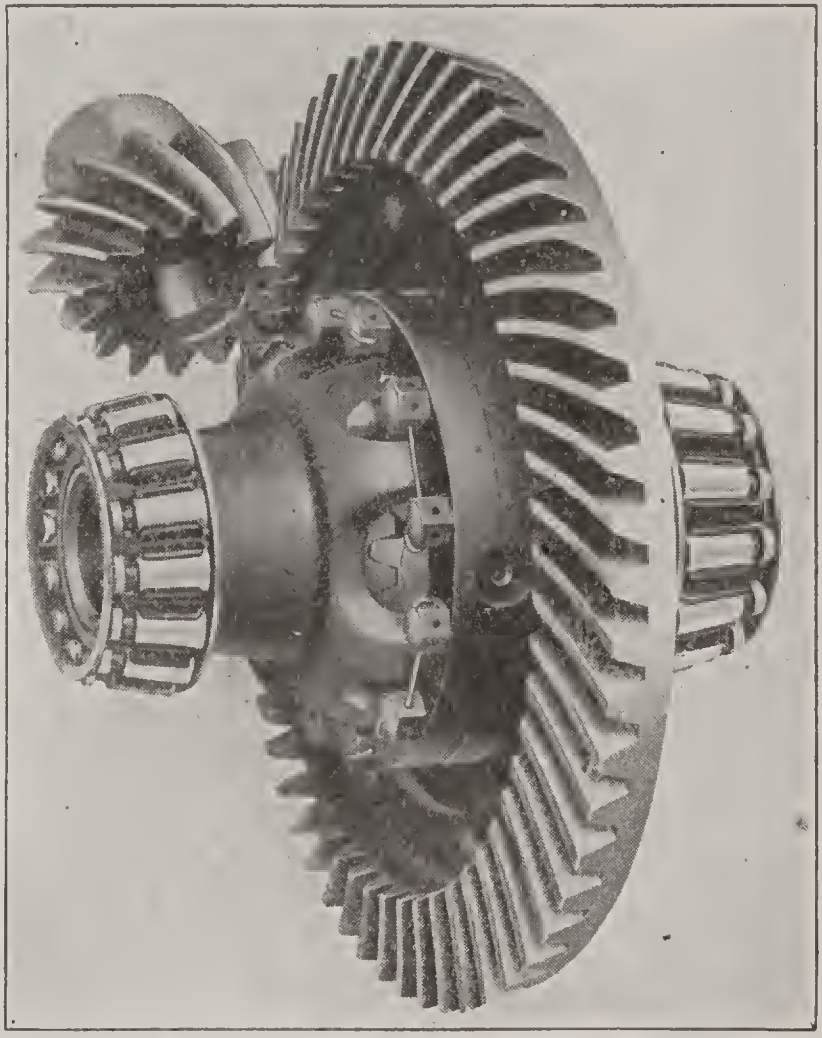


Fig. 435. Spiral Bevel Gears—a New Noiseless Type for Rear Axles
Courtesy of Timken-Detroit Axle Company, Detroit, Michigan

As soon as the bevel gear final reduction disclosed its limitations and disadvantages, designers started to displace it. One of the earliest forms of gear used for this purpose was the worm, an example of which can be seen in Fig. 434. This figure shows the worm placed above the wheel, but the lower position, which is also used, has the advantage of copious lubrication. In the form shown, the wheel must come directly beneath the worm so that the differential may be set inside of it.

The worm is usually more suitable for slower moving vehicles which have a large reduction of speed between engine and rear wheels, that is to say, it is peculiarly fitted to electrics and motor trucks of all sizes, on which it is finding wider and wider use. On pleasure cars of the average size and type where a speed as high as 50 m.p.h. or higher is expected by all concerned, it has not been found suitable and consequently is not being used.

A later form, which is designed to replace the straight bevel, is the spiral bevel. This is primarily a bevel gear with spiral teeth, the idea being to incorporate in the bevel gear the advantages of the spirally shaped worm tooth, without its disadvantages. As Fig. 435 shows, this makes a very compact and neat arrangement, the differential fitting within the larger gear in the same manner as with the worm.

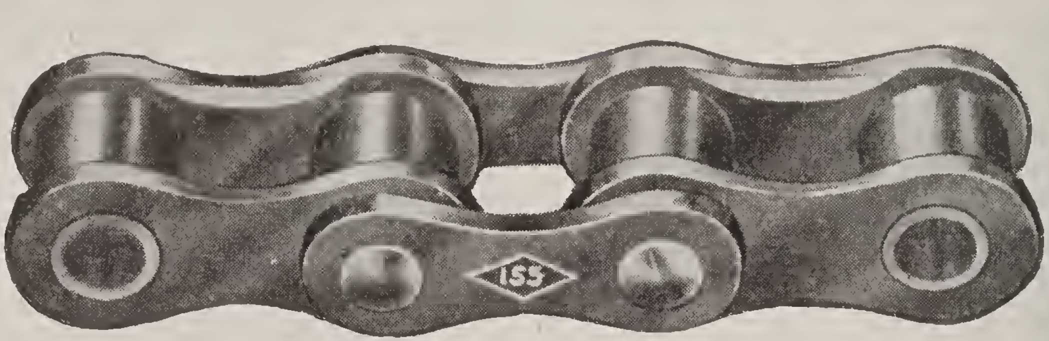


Fig. 436. Typical Roller Chain

Double-Chain Drive. The use of double chains, by which the driving wheels of an automobile are driven from a countershaft across the frame of the machine, is a practice possessing a number of advantages. But because of the noise and quick wear with badly designed chain drives and the difficulties of completely enclosing the driving mechanism, chains are not now as popular as formerly. Nevertheless, the elimination of universal joints working through large angles and under heavy loads, the avoidance of heavy weights carried on rear axles without spring support, the lowering of the clearance by the differential housings, etc., are very real objections that the double chain avoids.

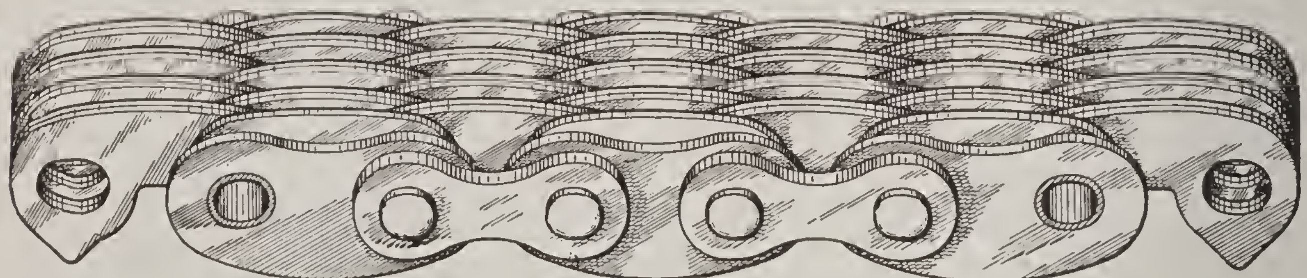


Fig. 437. Typical Silent Chain

For trucking and other heavy service, chains are still commonly in use, and it is the belief of many that a better understanding of their merits and the means of securing these merits in positive and permanent form will result in their more general use.

A typical roller chain of the type most used for automobile drives is illustrated in Fig. 436.

Silent chains, of the types illustrated in Figs. 437 and 438, possess certain points of superiority over roller chains and are therefore coming increasingly into use for camshaft drives, in gear boxes, etc., and there is some possibility that they will find more extensive application to final drives than at present.

The action of a silent chain is illustrated in Fig. 438, in which it is seen that as the chain links enter the sprocket teeth the chain teeth at the same time close together and settle in the sprocket with a wedging action that causes them to be absolutely tight, but without any more binding than there is backlash.

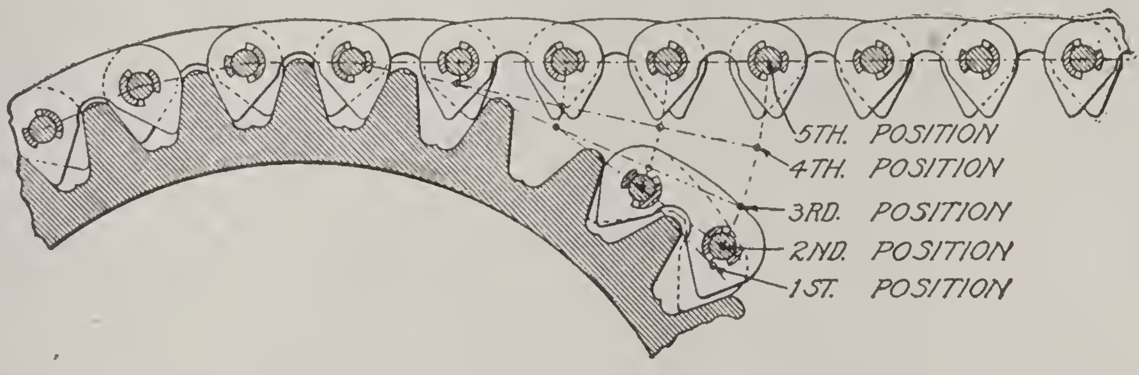


Fig. 438. Action of Silent Chain and Sprockets

To keep silent chains from coming off sidewise from the sprockets over which they run, it is customary to make the side links of deeper section than the center links, as is illustrated in Fig. 437. Another successful scheme is grooving the sprocket to receive a row of special center links in the chain, which are made deeper than the standard links.

At present, only one American pleasure car, the Metz, has final drive by means of silent chains. This is a small car with a friction transmission, the drive from the ends of the cross-shaft being by enclosed silent chain to each rear wheel.

Torque Bar and Its Function. It is a well-known fact that action and reaction are equal and opposite in direction, so that if a gear is turned forcibly in one direction, say clockwise, there is a reaction in the opposite direction, or counter-clockwise. This is the simple basic reason for a torque bar, or torque rod, on an automobile. It is needed with any form of final drive, but it takes different forms, according to the type of gear used. The bevel and spiral bevel used on 88 per cent of the 1917 cars are explained in detail as follows: Fig. 439 shows the rear end of a typical pleasure-car chassis. The engine is rotating clockwise, and so is the driving shaft *A*, as shown by the arrow. The shaft turns the pinion *B* in a clockwise direction, which rotates the large bevel *C* so that its top turns toward the front of the car. The bevel *C* turns the rear axle *D* and the rear wheels (not shown) in the same direction; so the car moves forward.

In addition to the gear *C* and shaft *D* turning easily in the axle housing *E*, there is an equal and opposite reaction which tends to keep them stationary, while the bevel pinion *B* and driving shaft *A* tend to rotate around the rear axle as a center in a counter-clockwise direction, as shown by the diagram. If the rear axle were held firmly so it could not rotate, and there was nothing to restrain the bevel pinion and shaft, this could easily happen. However, since we do not wish this to happen, a means is provided to oppose this action and prevent it from happening. Since the turning force which makes the shaft rotate is called the torque, this rod, bar, or tube, whatever its form, is called the torque member.

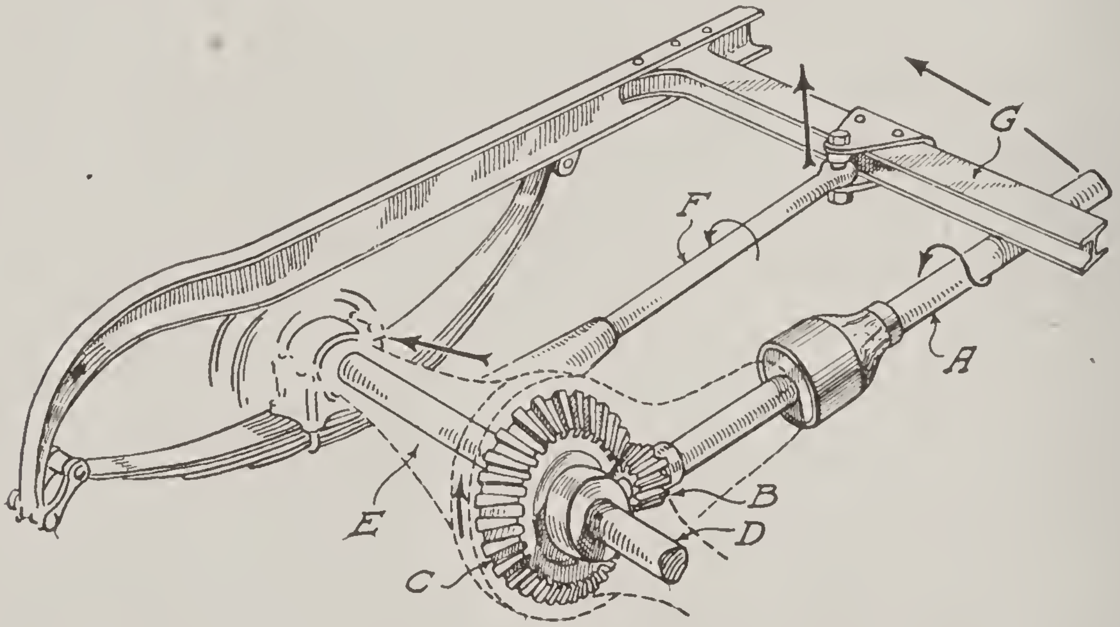


Fig. 439. Diagram to Show What Torque Is and Why Torque Rods are Necessary

In the sketch, the torque member is marked *F* and is attached to the frame cross-member *G*, between a pair of springs, so as to cushion the shocks of sudden car or shaft movements. The force on this is the force which tends to rotate the driving shaft and pinion counter-clockwise, so that it works upward, as shown by the arrow. The frame prevents this and absorbs the force.

Driving Reaction. As has been stated, the power, or torque, of the motor is used to rotate the rear wheels. These stick to the pavement or road surface, so the car is really pushed forward. Since it is this pushing action which really moves the car forward, it is very interesting to note how this push is transmitted from the wheels and rear axle to which they are attached to the frame which carries the body and passenger load.

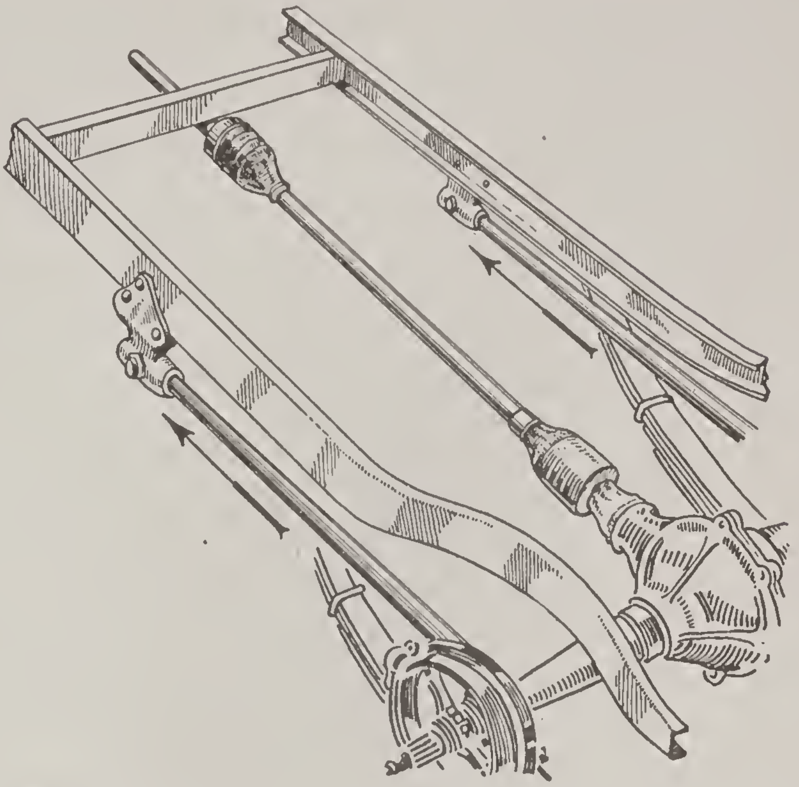


Fig. 440. Diagram to Explain Driving Reactions Using Radius Rods

The transmission of the drive to the body is accomplished in one of three ways. The first form was the so-called radius, or distance, rod, which the shaft-driven car inherited from the chain-driven form. In the chain drive, these rods were a necessity and served a double purpose; they kept the driving and driven sprockets the proper "distance" apart for correct chain driving (hence their name "distance" rods), and they also transmitted the drive back to the frame. On the shaft-driven car, the distance function is not needed, so they are called radius rods. As shown in Fig. 440, they transmit the drive forward to the frame, thus propelling the car in the direction of the arrow, and they also keep the rear axle in its correct position.

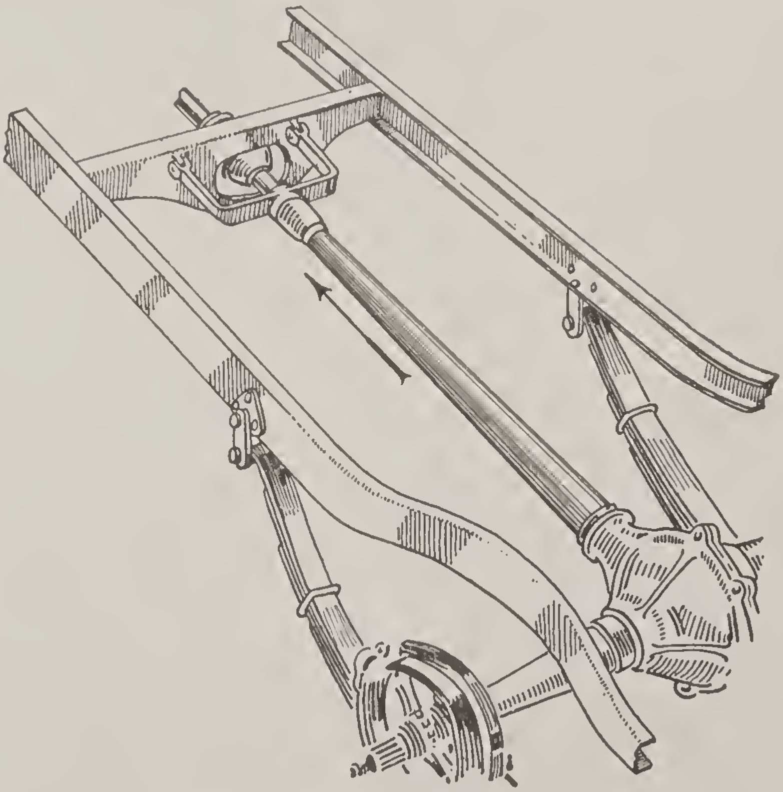


Fig. 441. Layout of Driving Reaction Using Torque Tube around Shaft

In lightening and simplifying the shaft-driven car, designers figured that three members for the torque and driving reactions were too many; so a design was worked out in which all three were combined into one, which is a form of tube surrounding the shaft. This made the member light but strong, and simplified the whole rear end. As shown in Fig. 441, the tube has forked ends at the front, which are connected to the frame cross-member in such a way as to absorb the torque reaction and also to transmit the drive. The method has the further advantage of needing but one universal joint, and that at the front end. Furthermore, it gives a correct radius of rise and fall for the rear axle, since the center of the combined torque and drive member is also the center of the universal joint in the driving shaft. In the form shown in Fig. 339 (radius rods not shown), the two different centers will be noted, the torque rod giving a greater radius than the shaft. Similarly, in Fig. 440 (where the torque rod is omitted for clearness), the rods give a longer radius of rear-axle movement than the shaft, which has a joint close to the axle.

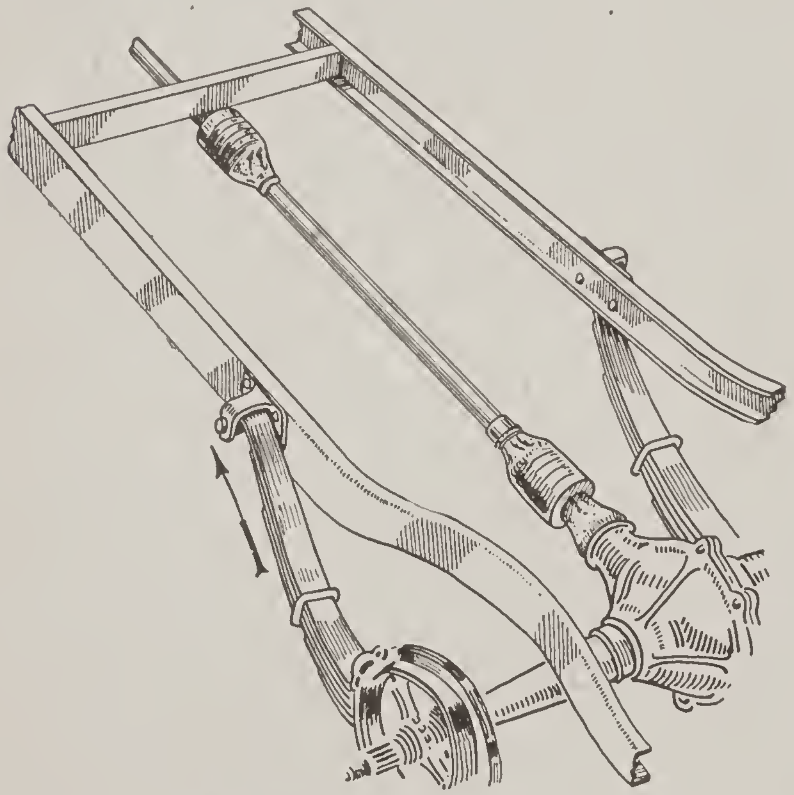


Fig. 442. Arrangement of Driving Reaction When Hotchkiss Drive is Used

It will be noted that both these methods allow complete freedom of the rear springs, which may be of any form, and shackled at the front end if desired by the designer. In its newest and simplest form, the so-called Hotchkiss, or spring, drive has both the radius and torque rods omitted, the springs being forced to transmit both forces, as shown in Fig 442. In this case, the forward end of the rear spring must act as a rod, or lever, instead of as a spring, and must be fairly straight and stiff without a shackle, but firmly pivoted on the frame. In addition, the shaft must have two universal joints, as shown.

It must be stated, as a simple fact, that this last form is increasing rapidly and at the expense of the other two. On smaller lighter cars it is gradually replacing all other forms. It has the advantages of minimum weight and fewer parts, and applies the driving force in a direct line to the frame, the same as the two radius rods do. On the other hand, it makes the springs serve a triple purpose, the demands on these for torque and drive transmission and absorption being such that the spring flexibility must be negligible, which makes the car ride hard. In addition, making the springs handle the three widely different actions puts additional stresses upon them, so that they are more likely to break. On the medium size and larger heavier cars, this construction is not gaining so rapidly.

TYPES OF REAR AXLES

Classification. Rear axles may be divided into the following classes, distinguished according to the method of carrying the load and taking the drive: the form in which the axle carries both load and drive; the semi-floating form, carrying the drive and a small part of the load, the axle shafts not being removable without removing the wheels; three-quarter floating form, carrying the drive and a small part of the load, the latter being divided between the shaft and its housing, but with the shafts removable; seven-eighths floating form, carrying the drive but not the load, the arrangement of bearings to take the load being such that the wheel hubs do not rest wholly and solely upon the axle-casing end; the full floating form, in which the shaft does nothing but drive, and is removable at will without disturbing the wheel and wheel weight resting on the axle-casing end, which is prolonged for this purpose.

The seven-eighths floating type has been developed to meet the need which arose for a floating construction, in which the axle casing did not pass entirely through the wheel hubs. With the full floating form, any accident to the wheel, in which it was struck from the side, also damaged the casing, or tube, end. The result of this in nine cases out of ten was to make the removal of the wheel impossible, because the tube end, which projected through, was bent over. Moreover, repairing in such a situation called for a new axle casing —a very expensive proposition. Consequently, the seven-eighths floating form was developed to present all the advantages of the full floating form, with this serious drawback eliminated by a rearrangement of the parts which did not necessitate prolonging the axle through the wheel hubs. Despite the facts, it did not gain as rapidly as the other floating forms, and now is almost out of use.

The three diagrams in Fig. 443 explain the types as well as words can. At the top is shown the full floating axle, the best but most expensive form. In the middle, the semi-floating axle, which makes the axle shaft do all the work—carrying load as well as transmitting power—is shown. At the bottom is the three-quarter floating form, which is really a combination of the other two forms and possesses a maximum of advantages with a minimum cost. The car weight is carried on the tubing, while the shaft drives and carries a portion of the side stresses to which the wheels are subjected, the quantity depending upon the construction of the bearings.

Of the 1917 cars, practically 30 per cent (29.5) have the three-quarter floating rear axle, 25.5 per cent the semi-floating form, and 43.5 per cent the full floating form. In 1916, however, the three-quarter form was used in but 22.8 per cent, and in 1915 in only 18.5 per cent of the cars. These figures show how the three-quarter floating axle has been gaining constantly at the expense mostly of the floating form, the semi-floating form practically standing still for three years.

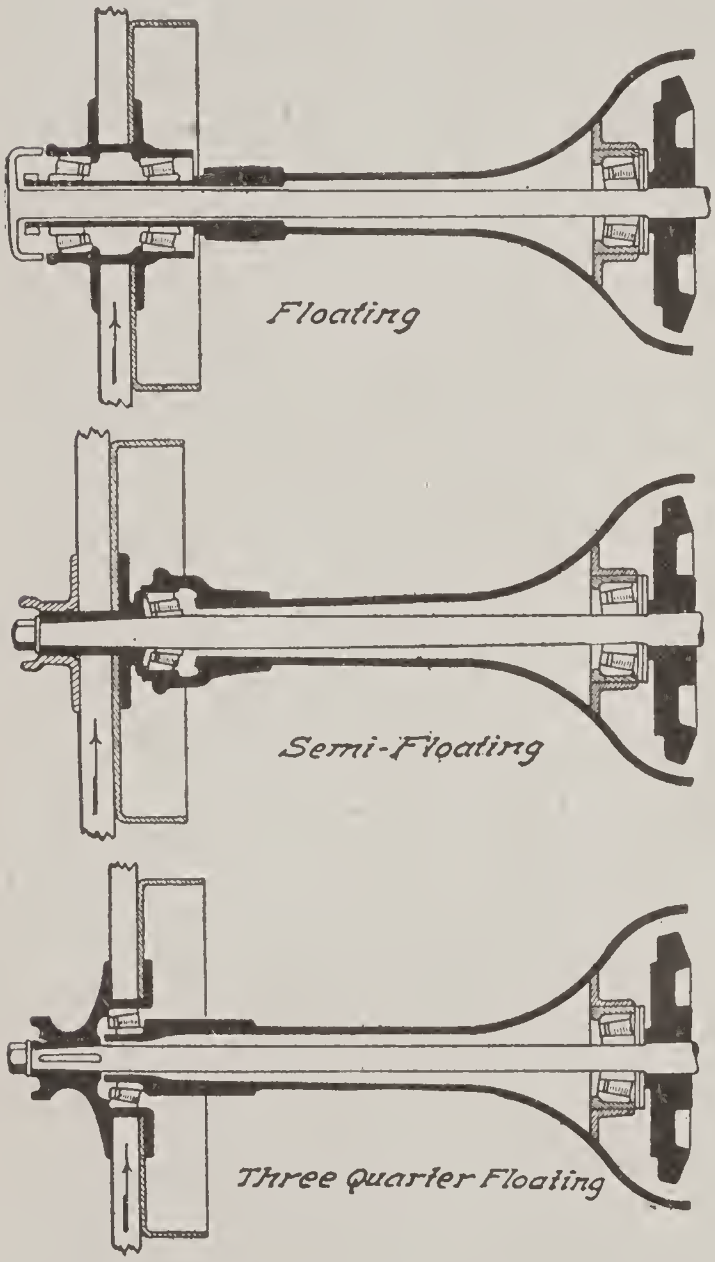


Fig. 443. Arrangement of Axle Bearings and Housing in Three Principal Forms of Rear Axle

Axle Carrying Load and Drive. The type in which the axle carried both load and drive was a peculiar one and did not last long. In this form, the rear-axle shafts were exposed and carried the weight of the load at the spring seats, which were bushed to allow the shafts to turn within them. This made a place which was hard to lubricate, and yet which was down in the dust and dirt, so that lubrication was a great necessity. All these causes, coupled with the fact that the axle carried both load and drive, caused its disuse.

Dropped Rear Axle of Full Floating Type. The dropped type of axle is not much used at present for cars of the shaft-driven type, the dropped part of the axle bed being used to hold the rearward-placed transmission. Fig. 444 shows a former American type, in which the weight of the car as well as the weight of the load is carried on the I-section drop-forged rear axle, while the drive is transmitted from the transmission by the usual shafts, which carry no load. The cut shows the complete assembly above and the dropped axle below. The round ends of the I-beam axle are hollow, carrying the driving shaft through the central hole and the wheels on bearings which fit over the outside. The wheels will revolve on the bearings, even if the inner shafts and transmission be removed from the chassis.

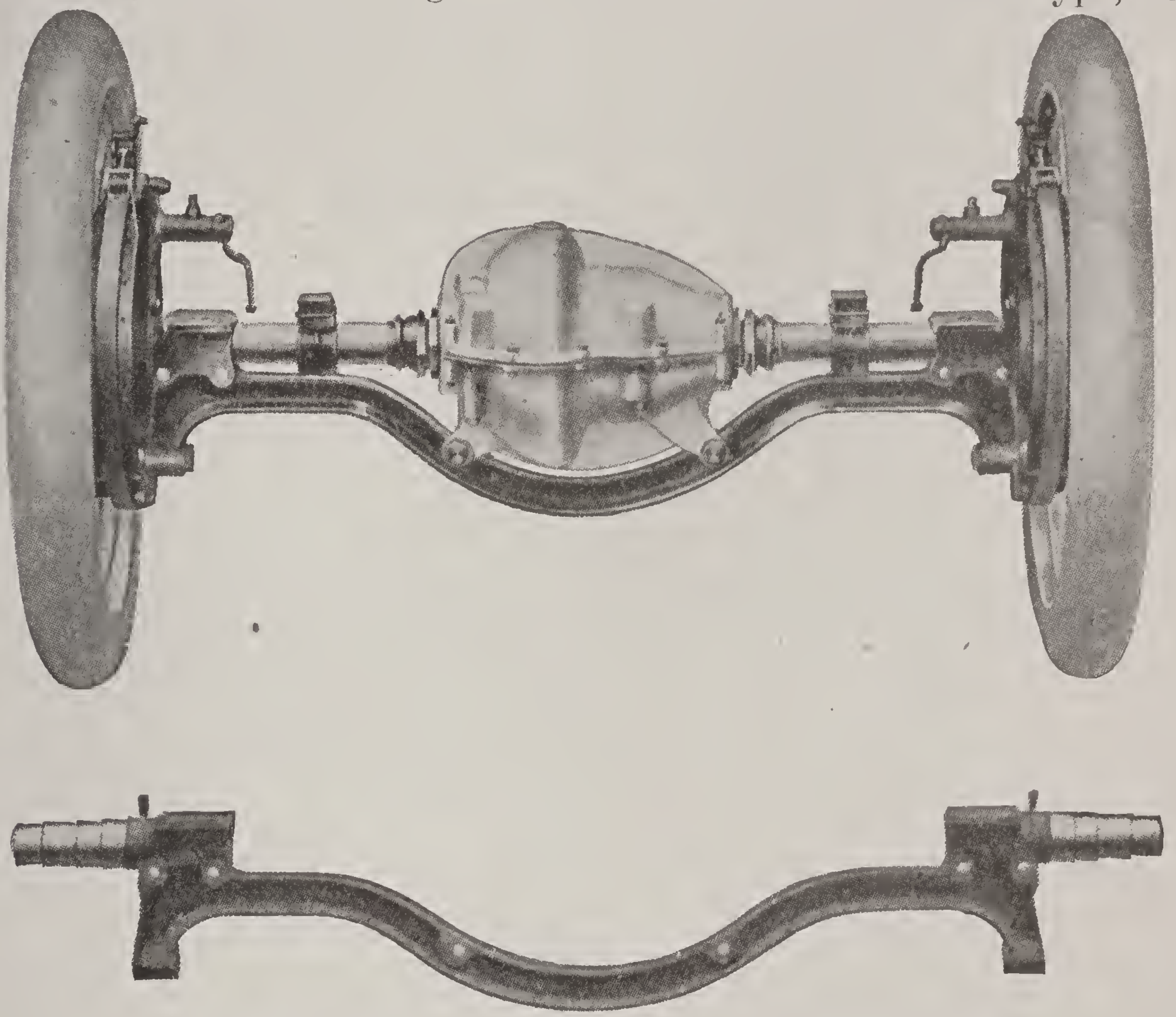


Fig. 444. Rear Construction Embodying Dropped Type of Rear Axle

Despite its manifold advantages, the expense of constructing an axle of this type—it is practically the same as that of two ordinary axles, making the total cost double that of any other form—has worked to prevent its general use. In fact, it is not now in use in this country, as the maker has gone out of business.

A prominent French constructor, De Dion, utilizes a dropped rear axle, but, in this, the differential casing and gearing are suspended from the frame and drive down to the axle shaft by means of a pair of short inclined shafts with two universal joints in each, that is, the drive from the differential to the two wheels contains four universal joints. The inevitable loss due to the necessarily short inclined shafts and to the two joints in each has deterred other manufacturers from using this form, although a few makers—notably the Peerless Company—have inserted a pair of joints in the rear axle in order to give the rear wheels the same camber as the front wheels. As this necessitates inclined shafts, the joints are needed to connect the horizontal center part with the inclined ends.

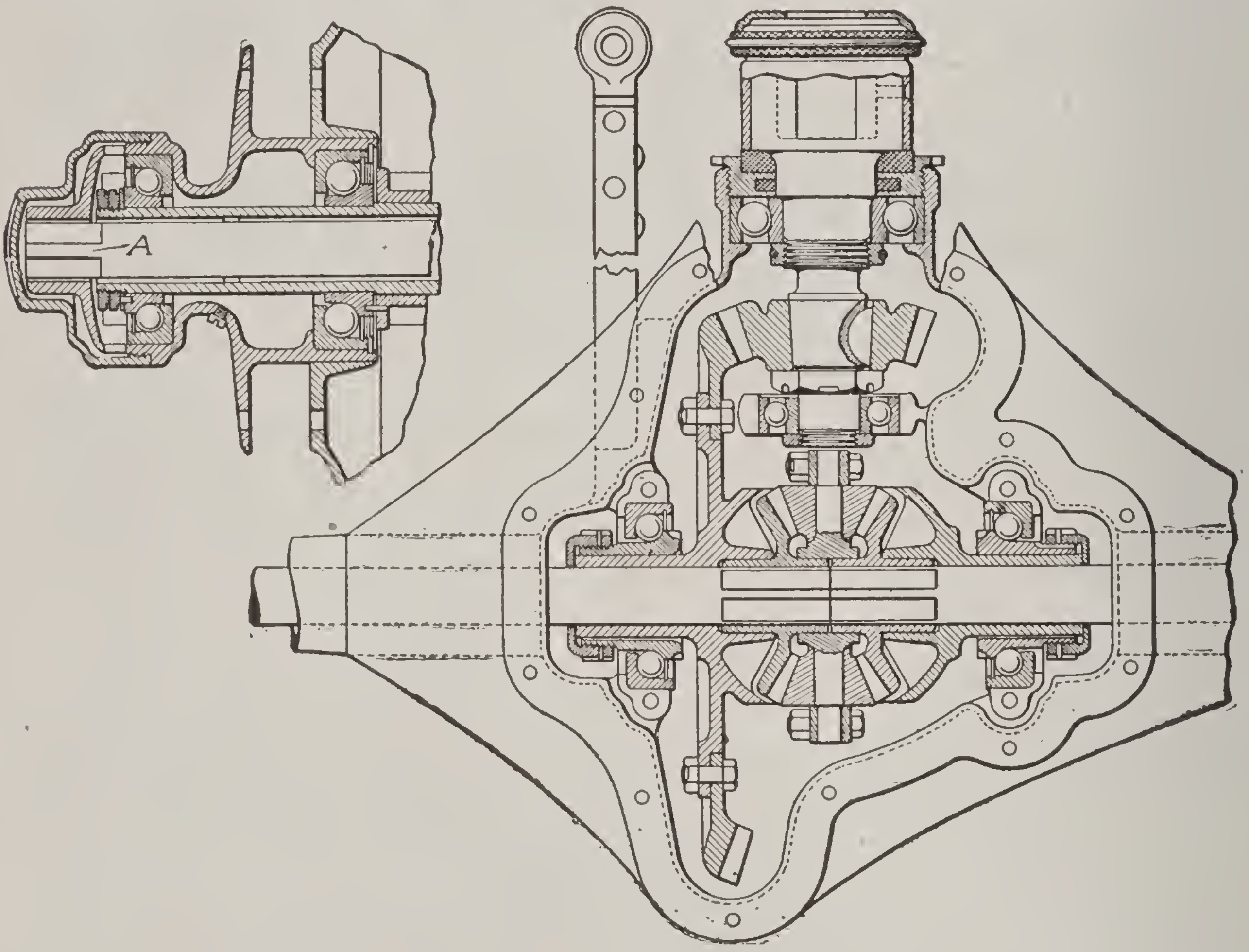


Fig. 445. Typical Ball-Bearing Differential

Clutch Forms in Semi=, Three=Quarter, and Full Floating Types. The main point of difference in the various semi-, three-quarter, and full floating axles, aside from the principle of design which makes them decidedly different, is the clutch, by means of which the wheel is driven. In some cases, this clutch takes the form of a gear, with straight sides and external notches, or jaws, to correspond with the teeth, but usually it is more of a claw type, the driving ends projecting inward from the point of attachment to the axle shaft. Another notable point of difference—and one which makes a huge difference in the cost—lies in the machining of these jaws, whether they are attached to the axle or machined up with it in one piece. The latter is considered better and stronger in every way, but, as it is much more expensive, it is used only on the best cars.

The driving clutch takes various forms, one of which is shown in the Studebaker axle, Fig. 445. In this type, the axle is a square rod acting within a square hole in the hubs. In the small detail at the upper left-hand corner the letter *A* shows the square upon which the driving clutch is slipped. The spaces at the inner ends of this indicate the clutches, or jaws, which mesh with corresponding slots on the wheel hub and thus do the driving.

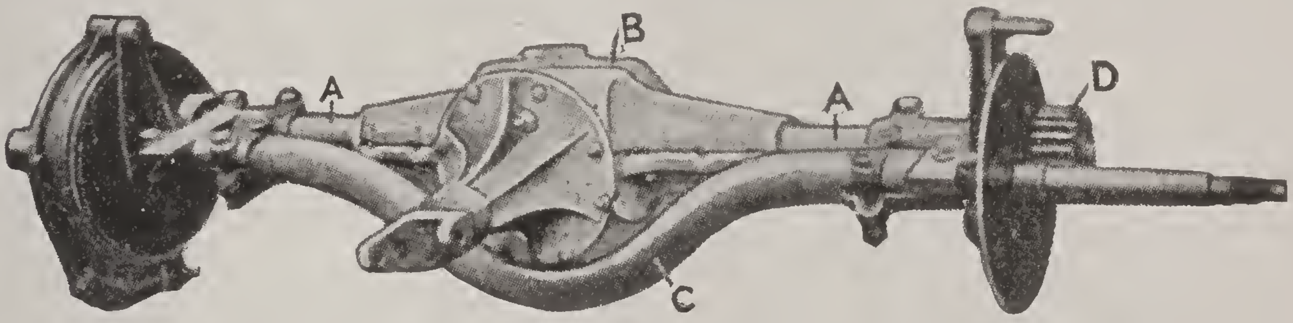


Fig. 446. Rear Axle, Showing Wheels Driven by Spur Gears

The dropped type of axles are neither all shaft-driven nor all chain driven. Fig. 446 shows one that is of the spur-gear driven type. The dropped axle bed *C* is of tubular form, and the differential case is dropped down on and slightly back of the rear axle, as at *B*. From this case, two shafts *A A* extend out to the sides, driving the wheels through the medium of the spur gear *D*, which meshes with internal gears within the wheel hubs (not shown). This type of rear axle and drive is used on a number of the Fifth Avenue stages in New York City.

Internal-Gear Drive for Trucks. The spur-gear driven type just described is gaining rapidly for motor-truck use, because it has a number of important advantages. Besides carrying the heavy load on a member able to withstand any amount of overload, it materially lightens the power-transmitting portion of the axle, which is enclosed and therefore quiet. It is simple and inexpensive to construct and repair. Fig. 447 shows a section through one of these axles, which is used on a very light truck of $\frac{3}{4}$-ton capacity. In this figure, it will be noted that the load-carrying axle is behind the power-transmitting shafts, consequently the former is straight. In Fig. 446, the load carrying axle is in front and consequently must be bent down at the center. This bend is a source of weakness.

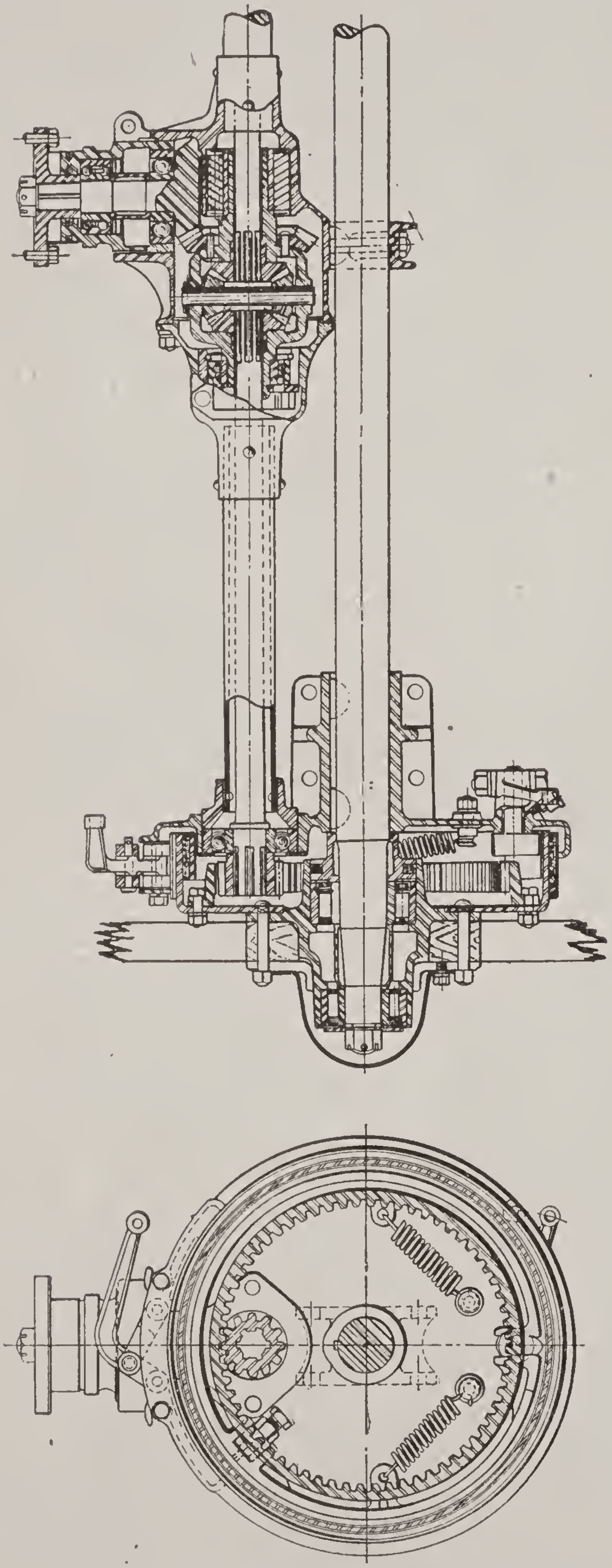


Fig. 447. Sectional Drawing through Internal-Gear Drive Axle of Three-Quarter Ton Capacity

Courtesy of Russell Motor Axle Company, Detroit, Michigan

Full Floating Axle. Fig. 448 shows a full floating axle, with the ends of the driving shafts projecting beyond the housing and carrying five jaws which mesh with five similar ones in the wheel hubs and thus drive the wheels. Unless the jaw end is welded on to the shaft, this makes a very expensive axle despite its many good points. Fig. 449 shows the rear construction of a car with full floating axle, with the brace below it for the purpose of strengthening the whole construction. The large diameter brake drums, shown close to the wheels, are made of pressed steel and are united to the axle tubing, which is also united to the differential housing, so that the whole forms one large and continuous piece, except where the differential unit bolts on one side and the cover on the other. Note that the shaft has the driving clutches machined as an integral part, and that removing the two shafts for a few inches makes it possible to unbolt and remove the entire differential unit. For the sake of comparison, Fig. 450 shows an axle which differs from Fig. 449 only in having spiral bevels substituted for the ordinary straight-tooth bevels. In

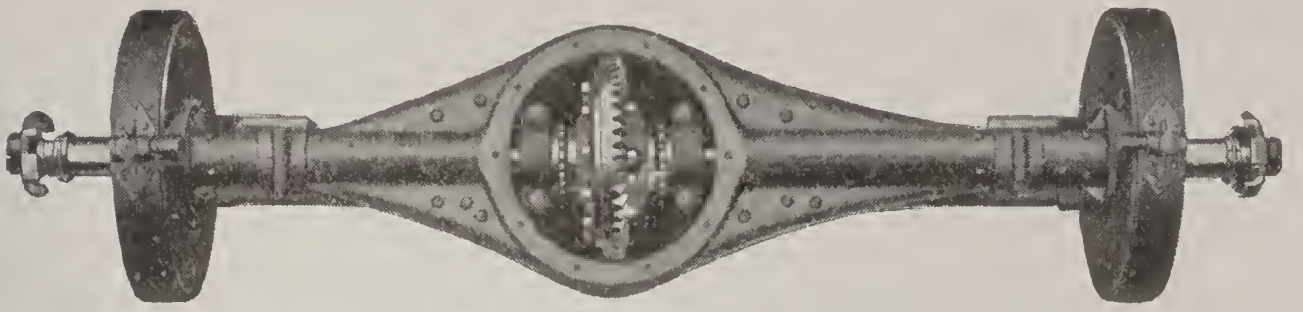


Fig. 448. Example of Full Floating Type of Axle

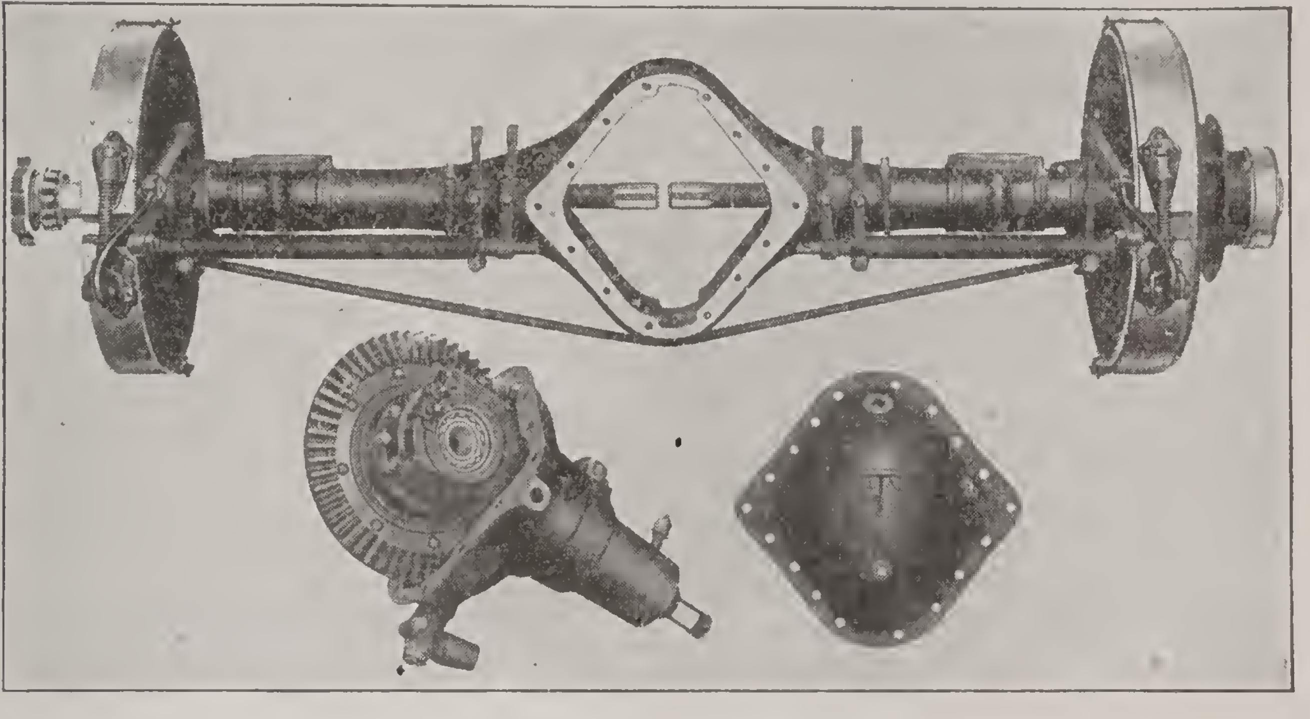


Fig. 449. Timken Full Floating Rear Axle, Showing Differential Removed
Courtesy of Timken-Detroit Axle Company, Detroit, Michigan

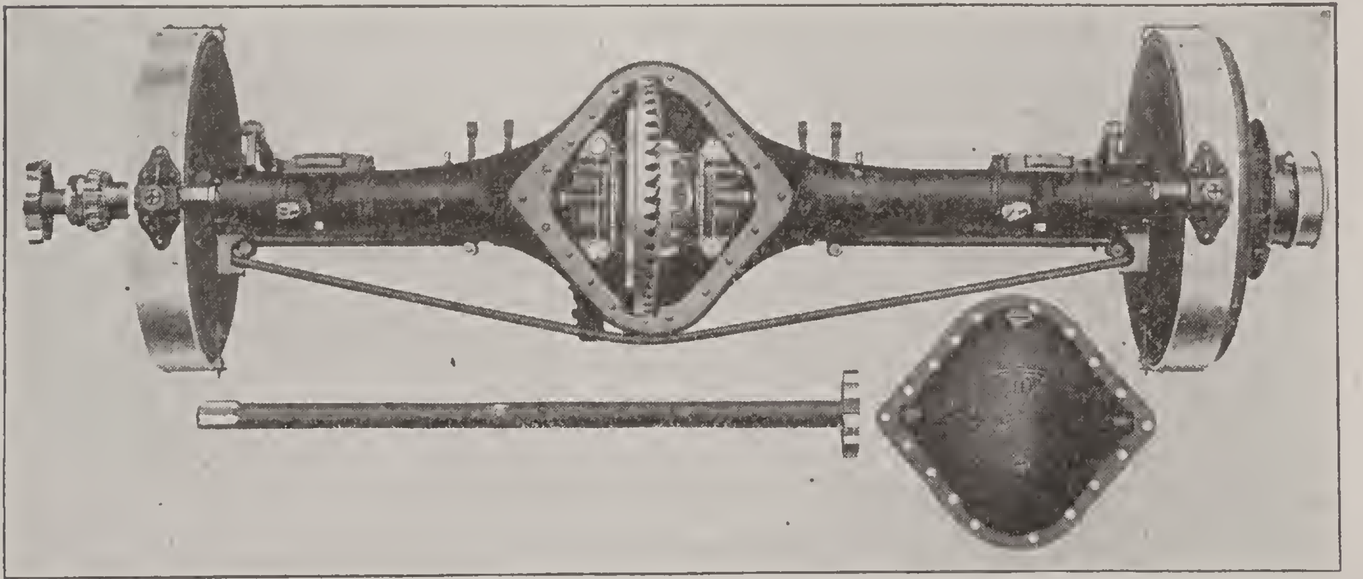


Fig. 450. Timken Full Floating Rear Axle with Spiral Bevel Gears

Fig. 450, the differential unit is removable in the same manner as in Fig. 449. One of the axle shafts, with its integral driving clutches, and the differential cover are shown below. Note the two plugs in the cover; the upper one is for filling the case with lubricant, while the lower plug acts as a level indicator. When it is opened, heavy oil or oil and grease combinations are put in the filling plug above until the lubricant begins to flow out of the lower opening.

Three=Quarter Floating Axle. An interesting study in rear axle design is seen in Fig. 451. This axle has a number of points in which it differs from previously described forms. It is of the three-quarter floating type. Note the enclosure of the driving shaft and the splines at its forward end for the universal joint, also the housing for the joint forming the torque member. The small roller bearing for the spigot end of the driving shaft beyond the bevel pinion is unusual; so are the diagonal distance rods, the spherical seat for the springs, the combination of drawn-steel tubes, steel castings, and pressed-steel cover for the axle housing. The wire wheel and its method of attachment will be seen, also the double set of brakes, internal and external

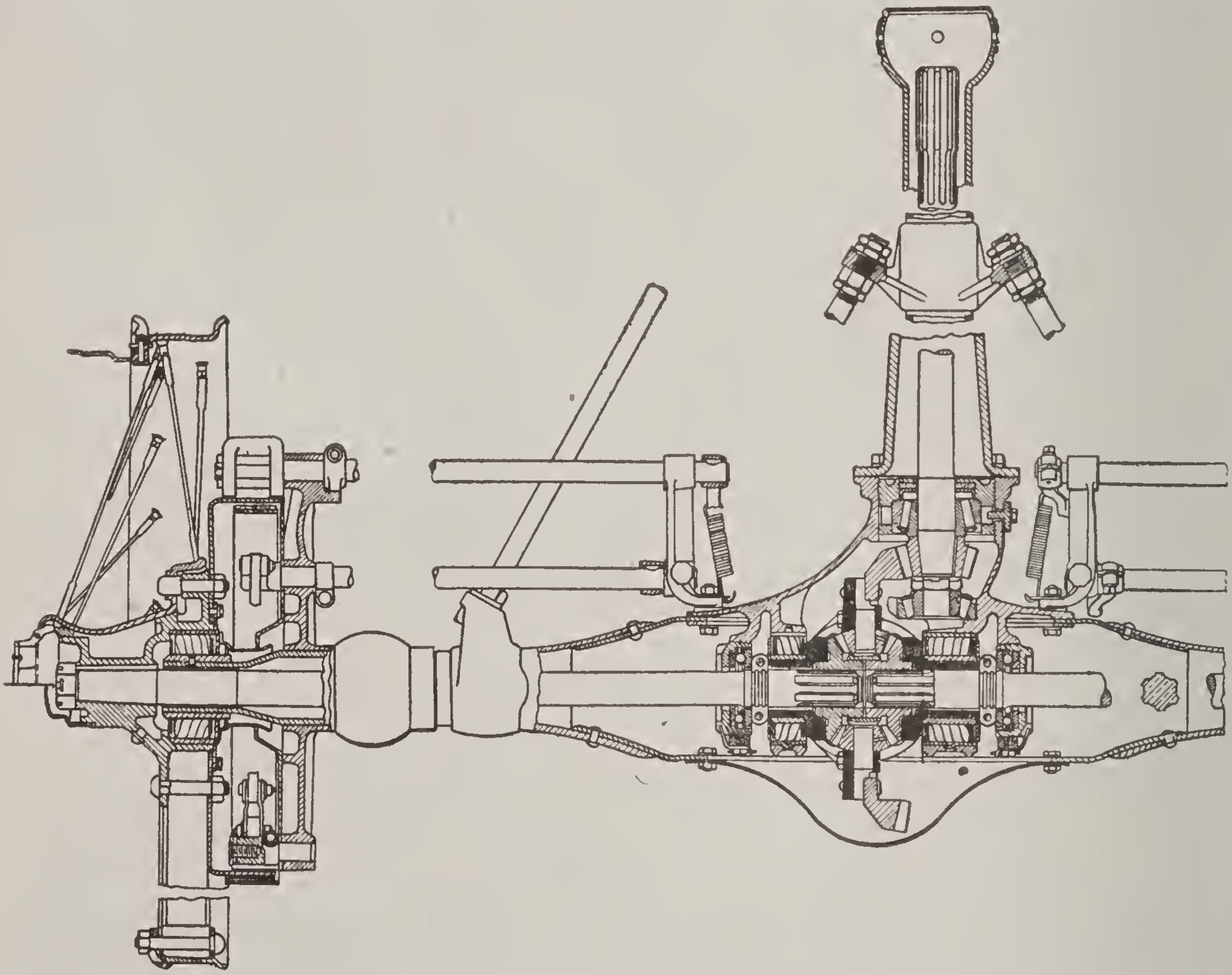


Fig. 451. Partial Section through Rear Axle of Case Car, Showing Construction
Courtesy of J. I. Case T. M. Company, Racine, Wisconsin

on the same drum, with operating shafts for both supported from the central part and ends of the axle housing.

Rear-Axle Housings. Rear-axle housings are usually of pressed steel, although castings play a very important part and are sometimes used alone and sometimes in combination with other castings or in combination with pressed steel. Aluminum, although not a dependable metal, is used quite a good deal for the purpose of saving weight, as excess weight upon the rear axle is anything but desirable. In one unusual but effective combination, the axle housing consists of two malleable-iron castings joined together by means of bolts at the centers, the brake drums being cast as a part of the tubes. While not usual, this is safe practice, for malleable iron is tough and will not break or splinter. It seldom is the case, however, that the axle casing is reduced to as few parts as are shown here.

Welding Resorted To. Where the differential housing or brake drums are of malleable iron, cast steel, or even of pressed steel, and it is desired to unite them with the steel tubing forming the main part of the shaft housing, welding is now universally used. Formerly, it was good practice to make the casing a drive fit on the tube, riveting it in place, or else soldering it in place, making doubly sure by using rivets. Now, however, welding is resorted to, either the oxy-acetylene, electric, or some other process being used.

In the axles shown in Figs. 449 and 450, it will be noted that the axle shell is of pressed steel, to which the spring seats are bolted, the remainder of the construction being formed by drawing. In Fig. 448, however, the construction is such as to necessitate making the two halves longitudinally and then bolting or spot-welding them together. Being machined after they are fastened together, it makes as accurate a construction as the one-piece jobs, Figs. 449 and 450.

Effect of Differentials on Rear Axles. A differential gear, sometimes called a balance, or compensating, gear, is a mechanism which allows one wheel to travel faster than the other and which at the same time gives a positive drive from the engine. This device is a necessity in order to allow the car to go around a curve properly, for in doing so the outer wheel must travel a greater distance than the inner one during the same interval of time.

There are two forms of differential, the bevel type and the all-spur type, the latter differing from the former only in the use of spur gears instead of bevel gears. The principle used in both is that a set of gears are so held together that when a resistance comes upon one part of the train of gears the whole train will stop revolving around on a stationary axis and revolve around another gear as an axis, the first gear, in the meantime, standing stationary, or practically so, according to the amount of the resistance encountered. In the bevel type, a pair of bevels are set horizontally. Between the bevels is a spider with three or four arms, with a small bevel on the end of each. These small bevels mesh with the larger bevels at the sides and ordinarily stand still, rotating around on the arm of the spider as an axis by virtue of the continued rotation of the two side gears in opposite directions. When one wheel meets greater obstructions on the road than the other, thus holding it back, the shaft which drives that wheel lags behind the shaft driving the other wheel and thus holds back the horizontal gear attached to the shaft. This retarding movement allows the other horizontal gear more freedom to rotate. The result is that the spider carrying the smaller bevels rotates around on its axis, thus imparting to the free gear attached to the free wheel an additional motion, and to the free wheel a doubled speed, while the retarded wheel has a lessened speed. This takes the car around the corner without breaking the rear axle, as would be the case without some such contrivance. The description of the bevel differential action applies equally well to the spur type, except that all gears are spurs.

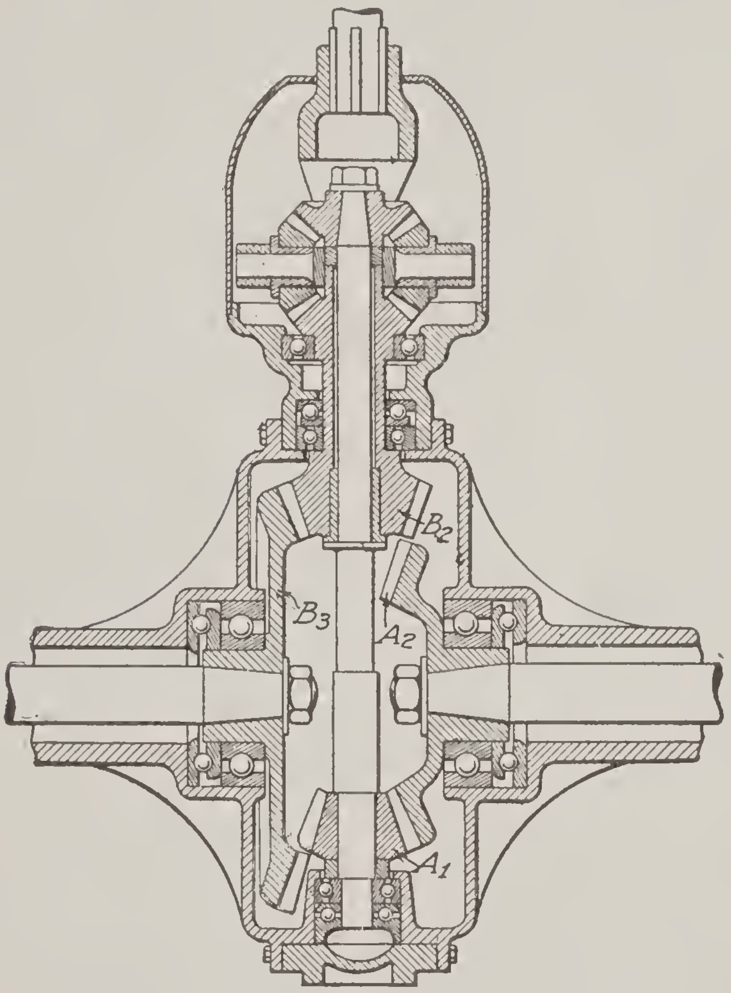


Fig. 452. Peculiar Differential Construction

The dividing of the rear axle is, of course, done to make a place for the differential gear to work, and much time and thought have been given to this subject in an endeavor to work out a substitute which would permit the differential action and still allow the strengthening of the rear axle. Fig. 452 shows one solution of the problem, which has been worked out in such a way that the differential is moved forward into the driving shaft. The rear axle shafts are thus greatly strengthened, the designer being unhampered by the presence of the differential in the rear axle. In this design, one side gear of the bevel-gear differential is carried upon a shaft, and the other upon a tube around the shaft. Then, at the rear axle, two sets of bevel gears B_2B_3 and A_1A_2 are used, A_1 being driven by the main shaft, and driving the right-hand shaft through the gear A_2; while the other B_2 is driven by the tube, and drives the left-hand shaft through the gear B_3. In this case the axle shafts are made much larger than in the ordinary case, while the differential action is just the same.

Improved Forms of Differential. Lately, much work has been done upon differentials to cause them to act as differentials should. The present form of differential acts according to the amount of resistance offered, but should act according to the distance traveled. When no resistance is offered, all the power is transmitted to that wheel, leaving the other stationary. This is just the opposite of the desired effect. If a differential were constructed to work for distance only, then, in the case of a wheel on ice or other slippery surface which offered little or no resistance, both wheels would still be driven equally, and the power transmitted to the one not on the ice would pull the vehicle over it.

One way in which the differential action might be corrected is by the use of helical gears and pinions instead of the usual bevel or spur gears. In the M & S forms, this construction is used, Fig. 453, showing the form constructed by Brown-Lipe-Chapin. In this form, each axle shaft carries a helical gear, and the differential spider carries two helical pinions with radial axes and four additional pinions, each of which meshes with one of the radial pinions and one of the gears on the axle shafts. On a turn, the outer wheel tends to run ahead of the inner and thus causes the nest of helical gears to revolve. All gears and pinions have a right-hand 45-degree tooth, so that one wheel may revolve the housing if the other is locked or held, but it is impossible to turn the free road wheel by pulling on the housing. The principle is the same as a worm steering gear in which the turning of the hand wheel may be transmitted to the front wheels, but the gear cannot be operated from the wheel end, because the worm is irreversible. This differential is used to advantage to prevent spinning on slippery ground and also to eliminate the skidding which the ordinary differential gives.

Another somewhat similar device has but two pairs of helical pinions in addition to the two helical gears on the shafts, the axes of each pair being set at an angle to the others. Thus, each helical gear and its pinion form an irreversible gear combination, so that movement cannot be transmitted through either in the reverse direction. This form fulfills the same conditions as the Brown-Lipe-Chapin M & S form, as the construction is such that no motion can be transmitted from the differential spider or housing to one of the wheels alone.

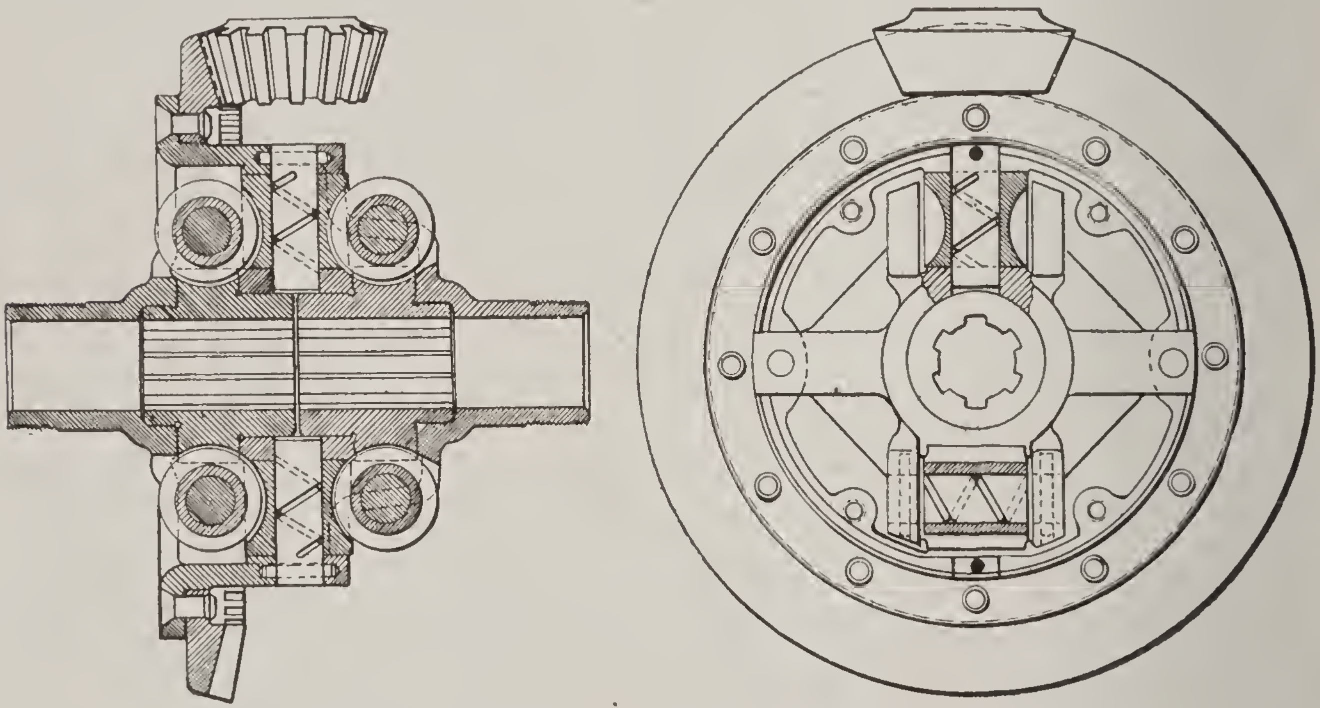


Fig. 453. The M & S Helical Gear Differential in Sections
Courtesy of Brown-Lipe-Chapin Company, Syracuse, New York

The above principle is back of the gearless form, shown in Fig. 454, in which the result is achieved through ratchets instead of helical gears, the lack of gears giving it its name. In this form there are two ratchets *Y* and *Y1*, which are keyed to the two axle shafts and free to rotate independent of the housing. The round members marked *B* are the interlocking pawls; the upper one is in a tooth of the right-hand ratchet at the right and is driven by the contact face of the driving sector *X* at the left. Thus, the right-hand ratchet is being driven positively forward. The lower pawl is engaged at the other end; so the left-hand ratchet is also being driven positively forward. On a turn, one wheel revolves faster than the other, say the right, and causes the right-hand ratchet to move faster than the differential housing, which can only go as fast as the other, or slow-moving, wheel. Then, the right-hand ratchet pushes the end of its pawl out of the tooth and gives it a free movement forward. As soon as the wheels revolve at equal speeds, the spring pushes it back. In the figure, the right-hand portion shows the original form in perspective.

Possible Elimination of Differential. The whole modern tendency is toward differential elimination. In the cyclecars and small cars brought out in recent years, designers have been forced to get along without it because of the demand for simplicity, light weight, and low price. This effect has been obtained by the use of a pair of driving belts, letting one slip more than the other; by the use of friction transmissions; by simply dividing the rear axle and letting one side lag when there was resistance; by not dividing it and letting one wheel drag; and in other ways. The evident success of these small vehicles without a differential or any real substitute for one has set designers to thinking about this subject again, and some big cars without a differential, or with a more simple and less expensive substitute for it, may appear in the near future.

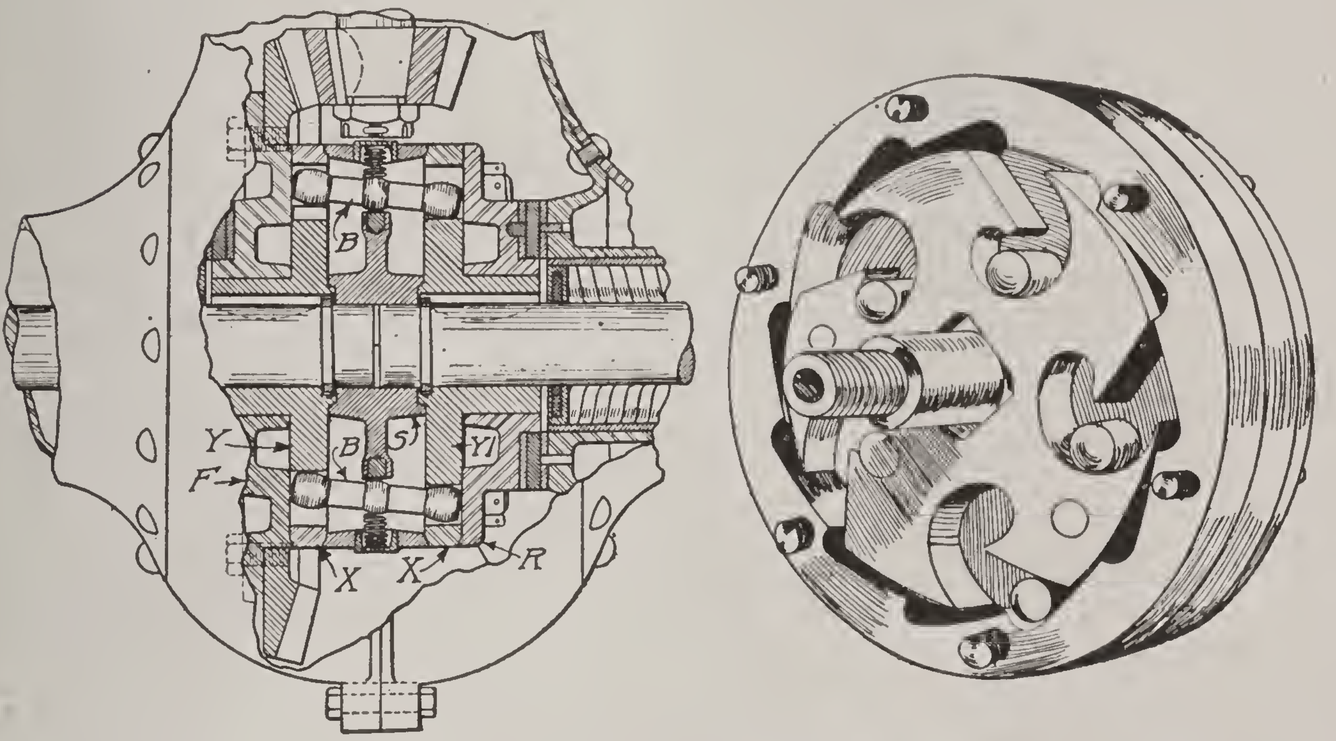


Fig. 454. Sketches Showing Construction and Operation of Gearless Differential

Rear=Wheel Bearings. The bearings used on rear axles differ very little from those used on front axles. All forms are used—plain bearings, ball bearings, ball thrusts, roller bearings in both cylindrical and tapered types, and all combinations of these. Thus, Figs. 445 and 452 show the exclusive and liberal use of ball bearings, while Fig. 451 shows all rollers of two kinds and ball bearings for thrust bearings only. The two kinds of roller bearings are the tapered roller and the flexible roller. Similarly, in Fig. 447, it will be noted that balls are used with two kinds of rollers, straight solid rollers in the wheels and flexible rollers in the differential case. Figs. 449 and 450 show the exclusive use of the tapered roller type, a construction which is gaining ground very rapidly, the same as in front axles, although, formerly, ball bearings were most widely used. The materials employed are similar to those used for front axles, which have been previously described. Cases are made of all kinds of steel and iron—pressed, drawn, cast, etc.—not to speak of crucible steel, malleable iron, manganese bronze, phosphor bronze, aluminum, aluminum alloys, and many combinations of these materials in twos and threes.

Rear=Axle Lubrication. Rear-axle lubrication is generally automatic in so far as the central bevel or other gears and the differential housing are concerned. The housing usually has a form of filling plug, or standpipe, which is used to fill the case with a form of heavy grease every 5000 miles, or once each season. The case is generally arranged so the filling plug works through and lubricates the outer bearings on the axle shafts as well, with suitable provision against this reaching the brake drums or other brake parts. The wheel bearings either are cared for in this way or have a central space which is filled with heavy grease once a season, being self-lubricating from then on. Such other rear axle parts as need occasional lubrication, as torque-rod pivots, brake-band supports, brake-operating shafts, etc., are generally provided with external grease cups, which are given a turn once a week on the average. It is highly important that the braking system be as well lubricated as the lubricating means provided will allow.

REAR=AXLE TROUBLES AND REPAIRS

Jacking=Up Troubles. Much rear-axle work—practically all, in fact—calls for the use of the jack. True, the full floating type of axle can have its shaft removed without jacking, but, aside from differential removal, there is little rear-axle trouble in which it is necessary to remove the shaft alone. In almost all cases, the axle must be jacked up. Many axles have a truss rod under the center, and this is in the way when jacking; however, this can be overcome. Make from heavy bar iron a U-shaped piece like that shown on top of the jack in Fig. 455, making the width of the slot just enough to admit the truss rod. The height, too, should be as little as will give contact with the under side of the axle housing.

Substitute for Jack. A good substitute for a jack is a form of hoist, Fig. 456, which will pick up the whole rear end of the car at once. This not only saves time and work, but holds the car level, while jacking one wheel does not. Moreover, with a rig of this kind, the car can be easily lifted so high that work underneath it may be easily done. The usual hoisting blocks are very expensive, but the above hoist can be easily made by the ingenious repair man. This one was made from an old whiffletree with a chain attached at each end. For the lower ends of the chains, a pair of hooks are made sufficiently large to hook under and around the biggest frame to be handled. With the center of the whiffletree fastened to the hook of a block and tackle, the hoist is complete. By slinging the hooks under the side members of the frame at the rear, it is an easy matter to quickly lift that end of the chassis any distance desired.

Workstand Equipment. Next to raising the rear axle, the most important thing is to support it in its elevated position. To leave it on jacks is not satisfactory, for they will not raise the frame high enough, and, furthermore, they are shaky and may easily let the whole rear end fall over, doing considerable damage. With the overhead hoist, the chains or ropes are in the way; so a stand is both a necessity and a convenience. In Fig. 457, several types of stands are shown. *A* is essentially a workstand, intended to hold the axle and part of the propeller shaft while repair work is being done thereon. It consists of a floor unit, or base, built in the form of an *A*, with six uprights let into it, preferably mortised and tenoned for greater strength and stiffness. Then, the four rear uprights are joined together for additional stiffness and rigidity. If casters are added on the ends, the stand can be more conveniently handled around the shop.

The forms *B* are for more temporary work and consequently need not be so well or so elaborately made. The little stand *C* is a very handy type for all-around work. Stands of this kind with the top surface grooved for the axle are excellent to place under cars which have been put in storage for the winter.

The stand *D* is, like *A*, a workstand pure and simple. In this, however, the dropped-end members allow supporting the axle at those points, while the elimination of central supports gives plenty of room for truss rods. This type of stand would preferably be made from metal, pressed steel or small angle irons being very good. Every repair shop should have a considerable number and variety of stands, made as the work demands them, to fit this particular class of work.

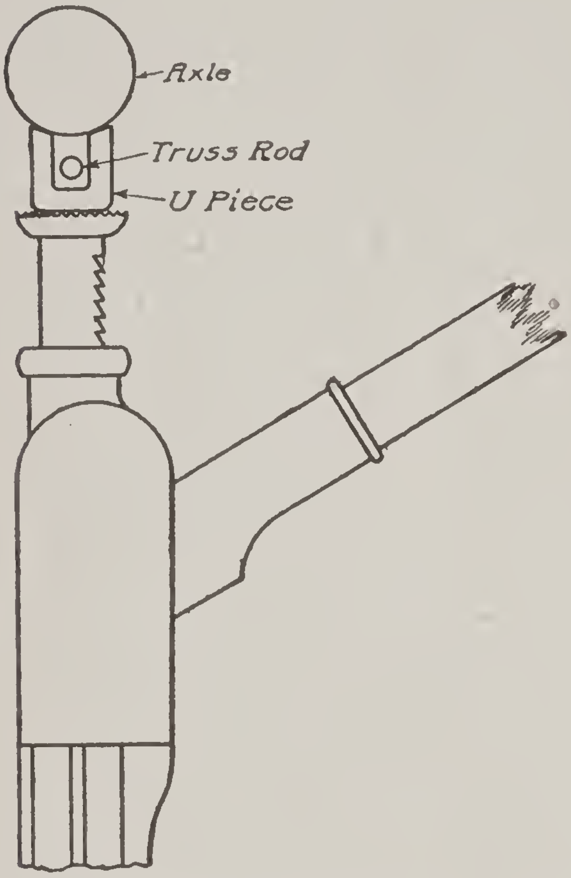


Fig. 455. Simple Arrangement for Avoiding Rear-Axle Truss Rod

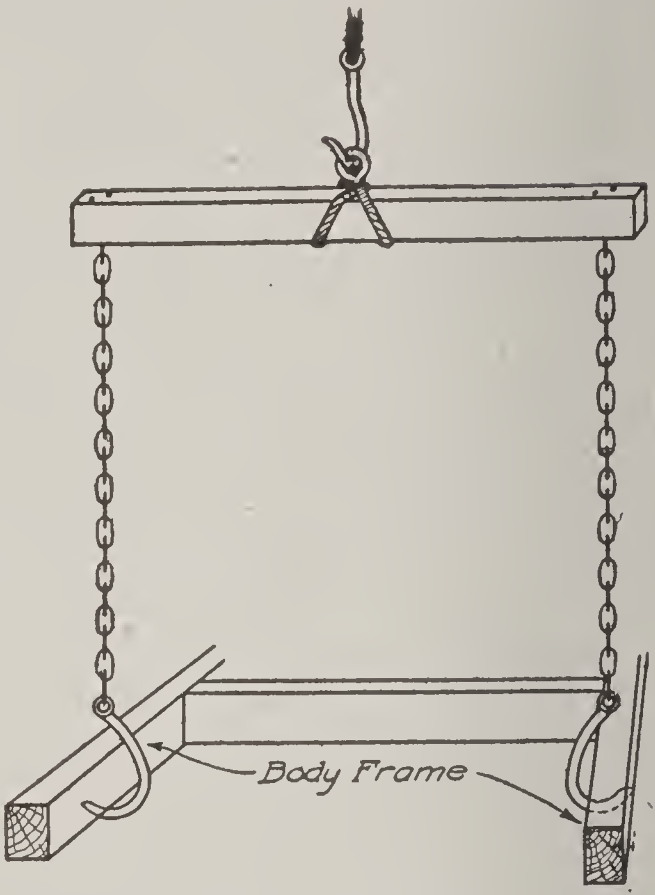


Fig. 456. Simple Automobile Frame Hoist

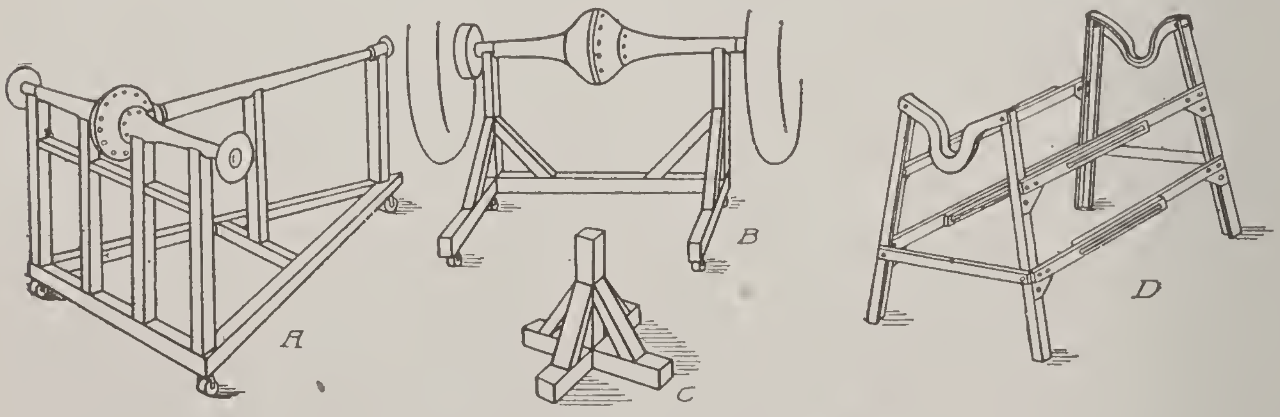


Fig. 457. Types of Handy Stands for Rear-Axle Repair Work

Universal-Joint Housings. Universal joints usually are covered with leather casings which are packed with grease. These keep out the dirt and, consequently, lessen the wear, and also lubricate the moving parts of the joints. A secondary function of the casings is to render these joints noiseless. If a car is not equipped with them, it is advisable for the owner to purchase them.

The shape of these casings, when opened out flat, would be not unlike that of two bottles with their flat bottoms set together, that is, narrow at the top and bottom and wider at the middle. All along both edges are eyelets for the lacing. The enlarged center fits around the joint, while the small ends encircle the respective shafts. To apply the casing, one end is placed around the shaft on one side of the joint, and the lace started; then the lacing proceeds, gradually drawing the ends together and around the joint. When this has been completed, and before the last end is closed, the whole is shoved back along the first shaft a little way, and the center portion half filled with a heavy grade of transmission grease. This done, the glove is pulled back into place, and the work of lacing completed around the second shaft. Both ends should be laced as tightly as possible, while the middle part should be loose. Sometimes these housings will become worn and make a very annoying chatter on the road, even when they are not sufficiently worn to warrant replacements. Under such circumstances, the offending member may be wound with tire tape held firmly in place in addition to its adhesive power by means of a hose clamp, as shown in Fig. 458. The coupling is held tightly enough to prevent the rattle and chatter, but not enough to interfere with its action. While not a handsome job, it does the business, stopping the noise effectively.

Rear Axle. Rear axles do such hard work and must stand up under such a large portion of the load carried in the machine that they offer many chances for wear, adjustment, or replacement.

Truss Rods. Truss rods hold the wheels in their correct vertical relation to the road surface and to one another. If, through wear or excessive loading, the axle sags so that the wheels tip in at the top, presenting a knock-kneed appearance, the truss rods must be tightened up. Usually, they are made with a turnbuckle set near one end, a locknut on each side preventing movement. The turnbuckle is threaded internally with a right-hand thread on one end and a left-hand thread on the other, so that a movement of the turnbuckle draws the two ends in toward one another, shortens the length of the rod, and thus pulls the lower parts of the wheels toward one another, correcting the tipping at the top.

To adjust a sagging axle, loosen both locknuts, remembering that one is right-handed and the other left. Then, with the wheels jacked clear of the ground, tighten the turnbuckle. A long square should be procured or made so that the wheel inclinations may be measured before and after. Placing the square on the ground or floor, which should be selected so as to be perfectly level, the turnbuckle should be moved until the tops appear to lean outward about $\frac{1}{2}$ inch—some makers advise more.

It should be borne in mind that even if the wheels and axle do not show the need of truss rod adjustment, if this rod be loose, it will become very noisy and rattle a great deal, as the rear axle sustains a great amount of jouncing. Moreover, this noise and rattle, if not taken up, will cause wear, which cannot be taken up.

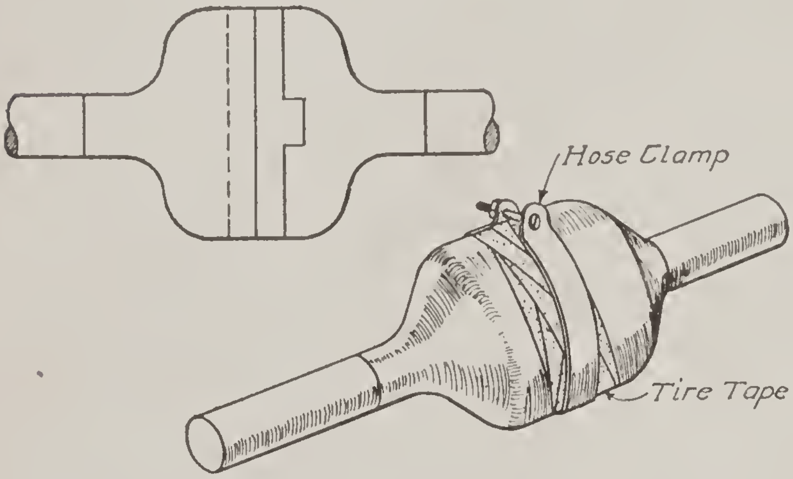


Fig. 458. Easy Method of Quieting Noisy Universal-Joint Housings
Courtesy of "Motor World"

Disassembling Rear Construction. In disassembling the rear construction for purposes of adjustment or repair, the repair man should be careful to mark all parts. Those parts which have been running together for several thousand miles act better and with less friction than would those which have never run together, despite the fact that the duplicate parts are supposed to be alike and interchangeable. It is therefore suggested that separate boxes be provided for the parts taken from the two ends or sides. The method of disassembling is about as follows: Jack up the axle, replacing the jack with small horses or blocks of wood if possible. Take off the hub caps, then free the wheels and take them off. Disconnect the brake-operating rods and levers and remove them from the car, marking them carefully. Spread the brake shoes apart, loosen the springs at one side, take out the springs, and then loosen and take out the brake shoes themselves. Remove the brake operating shaft with the cams;

then disconnect the spring bolts and jack up the chassis, using the spring for a support. Disconnect all torsion or radius rods and take off the grease boot around the universal joint in the driving shaft. Open this joint and disconnect the shaft. Take this off, and if the spring bolts have been removed, the rear axle will be free. Pull it out from under the chassis, and, if desired, further disassembling may be done more easily with the member clamped in a vice or laid on a bench.

Assembling. In assembling, almost the reverse of this process is followed, the parts going together in the opposite manner from that in which they were taken down.

Noisy Bevel Gears. If the bevel gears in the rear axle are noisy, the time to fix them is when the axle is disassembled, as this is quite a job. In general, bevel gears make a noise because they are poorly cut, because they are not set correctly with relation to each other, or because the teeth have become cut, or chipped, by some foreign material which has been forced between them.

In the first case, there is little the amateur can do beyond making the best possible adjustment and smoothing off any visible roughness. In the second case, it is simply a matter of setting one gear closer to or farther from the other by means of the adjustment provided. When the axle is disassembled, and all parts are readily accessible, it will be found that there is a notched nut on either side of each of the bevels; there should be a wrench in the tool kit to fit this. It is then a simple matter to move one outward and the other inward in either pair, according to which needs the adjustment. In case the teeth have become chipped, the projections should be smoothed down with a fine file, while the sharp edges of the cuts should be dressed in the same manner.

Packard Bevel Adjustment. Although strictly a transmission trouble, the older Packard cars have the transmission located on the rear axle, and this position made the adjustment of the bevel pinion difficult. For another thing, the shaft is very short and hard to hold. If the sliding gear on the shaft is meshed with the internal gear attached to the other end of the bevel-pinion unit, the latter will hold firmly, but there will still be a little play between the teeth. It is necessary to take this up, as otherwise the repair man would mistake this play for play in the bevel driving gear. It can be taken up as follows: Take an old sliding-gear unit from one of these transmissions, remove one of the teeth and slide the gear into position for meshing with the space at the top between two teeth on the good gear. Drive a pin in where the tooth has been removed, and this will fix the two firmly together without a particle of play. Then, by removing the cover from the differential housing, the bevels can be tested for play. Fig. 459 shows the transmission, bevel gears, and axle parts, also the gear with the tooth removed and replaced by a pin, so that the whole process will be clear.

Repair for Broken Spring Clips. The springs are held down on the axles by means of spring clips, which are simply U-shaped bolts with the inside width of the U equal to the width of the spring. Occasionally, these will break when they cannot be replaced or new ones forged. Under such circumstances, a repair such as used by one man, shown in Fig. 460, will always get the car home or to a garage where a better one can be made. This method of repair consists of a pair of flat plates, one above the spring, the other below the axle, with holes drilled in the corners to take four long carriage bolts, which happened to be handy. The plates were put on, bolts put in and tightened up, and the car was ready to run. Although an I-section axle is shown, this method of repair would work just as well on a round axle or on one of any other shape.

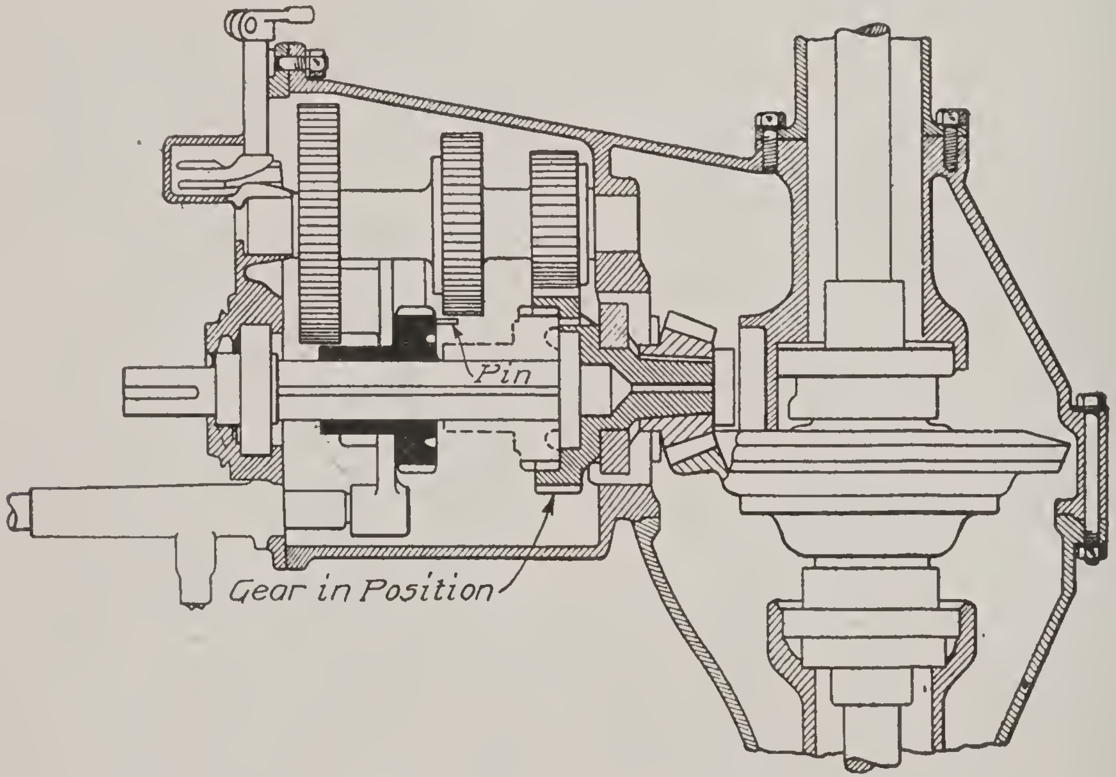


Fig. 459. Diagram of Packard Axle and Transmission to Show Adjustment of Bevel Pinion
Courtesy of "Motor World"

Lining Up Axles. In such a repair, however, the main thing is to get the rear axle lined up correctly, which is not an easy job. This may be done in the following manner: Get the car standing level on a nice clean smooth floor; hold a large metal square with a plumb bob hanging down over its short edge against the side of the frame. Move the square forward until the line just touches the rear axle at some set distance out from the frame, say 3 inches, as shown in Fig. 461. Then notice the distance this line is forward from the rear end of the frame. In the sketch it is 16 inches. Transfer the square and plumb bob to the other side and repeat. Here it will be found that the distance from the rear end of the frame is either more or less. In the sketch it is shown at 18 inches; so the difference, 2 inches, shows that the axle is out of alignment that much or half that, 1 inch at each end.

This axle is straightened by loosening the spring bolts and pushing one side back the distance apparently needed, then fastening tightly and checking up. If not correct, try again, using judgment as to which side should be moved. When finally satisfied that the rear axle is square with the frame, it is well to check this against the center-to-center distance of the wheels on each side. This is done by setting the front wheels exactly straight and then measuring from the center of the right front to the center of the right rear wheel. Then go over to the other side and measure the center-to-center distance of the left wheels. The two axles should agree exactly. If they do not, the rear axle prusumably needs more adjustment for squareness.

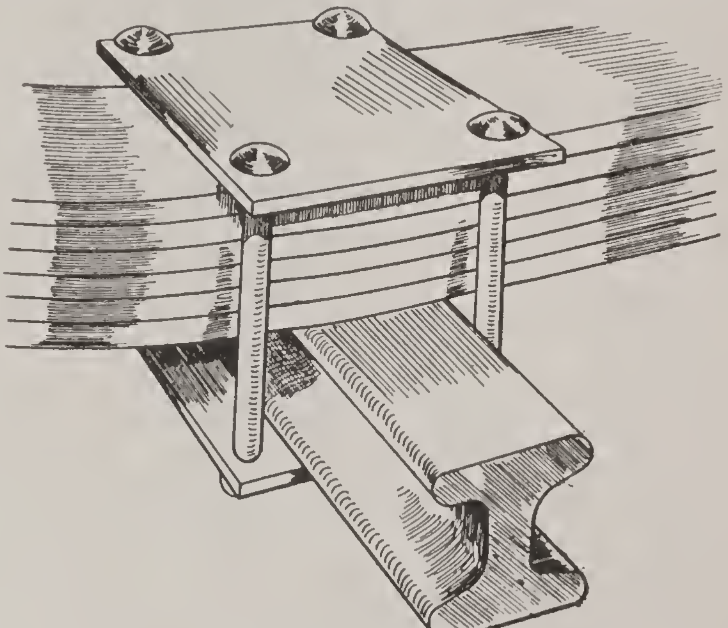


Fig. 460. How Spring Clips Are Replaced in Emergency
Courtesy of "Motor World"

Taking Out Bend in Axle. A simple method of repairing an axle which has been bent, but a method which is only temporary in that it is not accurate enough to give a job which could be called final, is that indicated in Fig. 462. The axle was bent when the hub struck an obstruction in the road, and it had to be straightened immediately.

A short length of 2 x 4 timber was cut to be a tight fit between the upper side of the hub cap and the roof beam. Then a jack under the axle at the point of the bend was raised. As the jack raised the axle, and the wood beam held the hub down, enough pressure was exerted to force the axle to give at the bend and return as nearly as possible to its original straightness. It was a quick and easy repair of the rough and ready order, which served when time was worth more than anything else; but it is a method which would not be advised or recommended when there was sufficient time to properly straighten the axle.

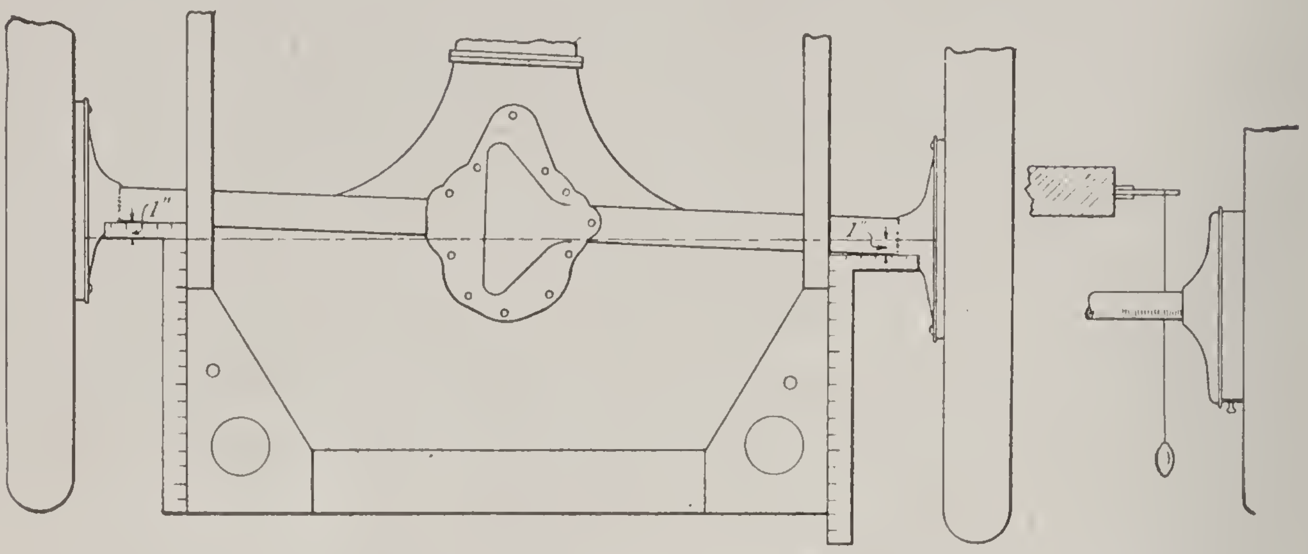


Fig. 461. Method of Checking up Rear-Axle Alignment with Square and Plumb Bob

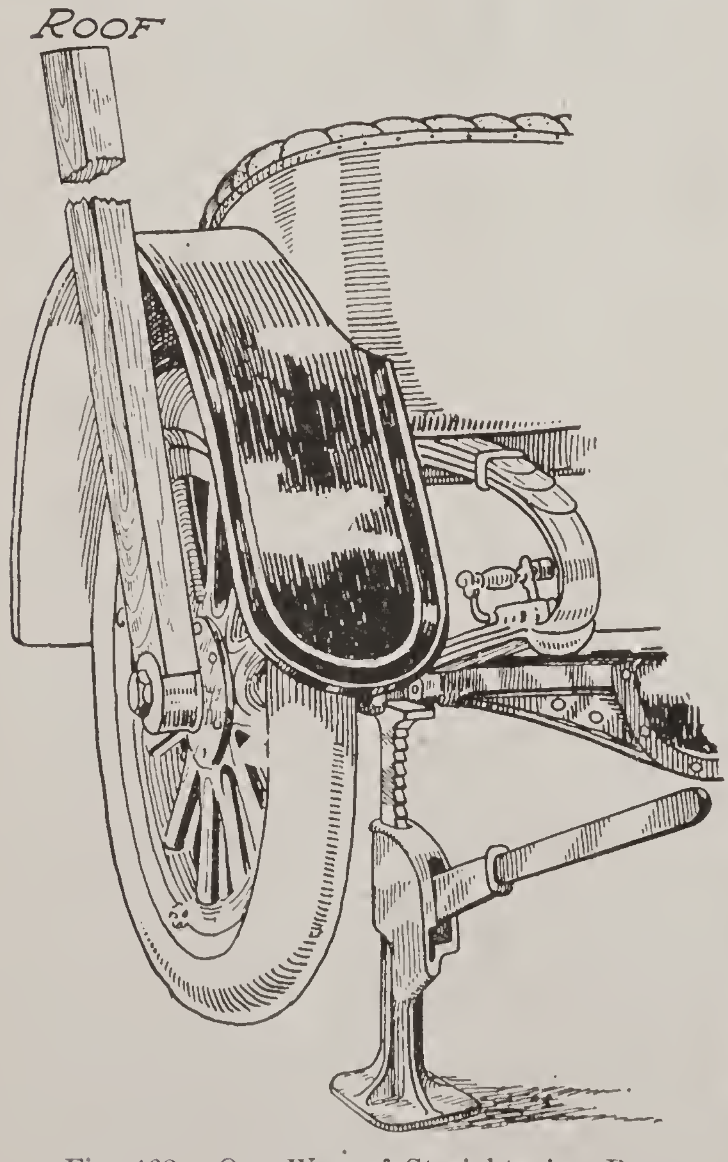


Fig. 462. One Way of Straightening Rear Axle Quickly

Locating Trouble. Many times, a car may be brought in for rear-axle repair on which the repair man cannot find any trouble. Many axles often develop an elusive hum, or grinding noise, which not only defies location, but is not continuous. The writer had such a case brought to him at one time, and was sure that the bevel gears were out of alignment and were cutting each other. It was a low-pitched whine which was not apparent at low speeds, but began to be heard around 18 to 20 miles an hour, and at times was very apparent. The noise was very annoying, but tearing down the rear construction showed absolutely no trouble; so the noise could not be at that point. Sometime later the noise was definitely located in a pair of worn speedometer gears on the right end of the front axle.

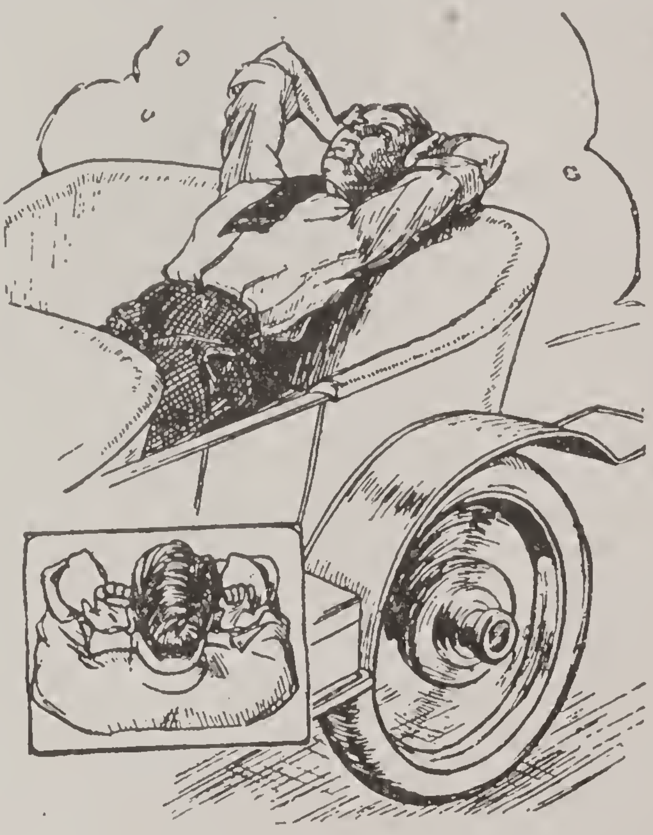


Fig. 463. Listening for Rear-Axle Noises

A good way to listen to rear axle hums out on the road is to lay back over the rear end of the car, Fig. 463, with the head against the top of the seat and projecting over slightly, and with the hands cupped in front of the ears, so as to catch every noise that arises. The larger sketch shows the general scheme, the small inset giving the method of holding the hands. When the sound arising from the axle is a steady hum, the gears are in good condition and well adjusted. If this sound is interrupted occasionally by a sharper, harsher note, it may be assumed that there is a point in one of the gears or on one of the shafts where things are not as they should be. By trying the car at starting, slowing down, running at various speeds, and coasting, this noise can be tied to something more definite, some fixed method of happening. In advance of actual repair work, including tearing down the whole axle, the gears can be adjusted. This can generally be done from outside the axle casing and without a great deal of work. If the adjustment makes matters worse, it can be reversed, or if it improves the situation, the adjusting can be continued, a little at a time, until the noise gradually disappears.

Checking Up Ford Axles. Many cases of Ford bent rear axles can be fixed without taking down the whole construction. The principal point is to find out how much and which way the axle is bent.

By removing the wheel on the bent side and placing the rig shown in Fig. 464 on the axle end, the extent of the trouble can be indicated by the axle itself. The iron rod is long and stiff, with its outer end pointed, and is fastened permanently to an old Ford hub. The rig is placed on the axle and held by the axle nut, but without the key, as the axle must be free to turn inside the hub. With the pointed end of the rod resting on the floor and with high gear engaged, have some one turn the engine over slowly, so as to turn the axle shaft around. As it revolves, the hub will be moved, and the pointed end on the floor will indicate the extent of the bend. By marking the two extreme points and dividing the distance between them, the center is found. Then a rod can be used as a bar to bend the axle, until the pointed rod end is exactly on the center mark. A little practice with this rig will enable a workman to straighten out a Ford rear axle in about the time it takes to tell it.

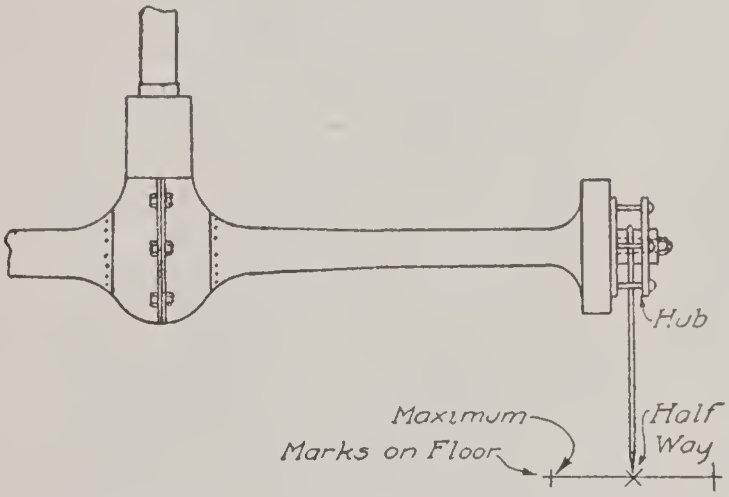


Fig. 464. Diagram Showing Method of Checking Up Ford Axles

BRAKES

Function of Brake. Next to power, applied through the correct form of gearing, and its final suitable drive to the road wheels, nothing is of more importance than the ability to stop the vehicle at will. One medium through which this is done, and which ordinarily suffices, is the shutting off of the source of power—in this case, the gasoline and the spark which is used to ignite its vapor. This will not always suffice, however, for the ordinary car possesses the ability to run at a speed of 40 miles per hour or upward, and weighs from 2000 pounds (one ton) upward to 4000 pounds (two tons). This combination makes for a large force of inertia, which will result in the car running for many yards, even hundreds of yards, after the power is shut off. It is for this reason that we must have a mechanical means of absorbing this inertia, or of snubbing the forward movement of the car. This is the function of the brakes, as fitted to the modern car.

Engine as a Brake. Although disregarded in any summary of brakes, the engine is the best brake possible, granting that the driver knows how to get the best results without doing any damage. The ordinary engine has a compression of from 60 pounds to 70 pounds per square inch, which is practically the pressure available when it is used as a brake. Since this is more pressure than any other type, or form, of brake will yield, its usefulness is self-evident.

Classification. Brakes are usually divided into two classes, differing mainly in location—the internal expanding and the external contracting. To these a third class should be added, because it partakes of the nature of both, yet differs from each one. This is the railway type of brake with removable shoes of metal, differing from the band type in that no attempt is made to cover the whole or even the greater part of the circular surface, but simply a small portion of it, against which a shoe is forced with a very high pressure. Both the other types are subject to division into other classes, the first into three subdivisions according to operating means, viz, cam, toggle, and scissors action.

Brakes are generally divided according to their location, as shaft and rear axle. The shaft brake at one time virtually went out of use, but it is now being revived. The marked swing toward the unit power plant, together with its simplification, lightening, and elimination tendencies, has produced a situation where a brake drum just back of the power and gear unit can be operated by the hand lever and a very short rod. In this way much weight and many parts are saved. An indirect advantage is that the brake is more accessible. With the worm drive, there is a marked tendency back to the shaft brake, particularly on motor trucks. Again, in the last few years, some work has been done with pneumatic, hydraulic, and electric forms of brake. With air under pressure for starting, and with water or electricity as needed for starting or for other purposes, it is a simple matter to utilize the same agency for braking, providing such use does not add too much complication and, at the same time, that it will give a superior method of snubbing the forward movement of the car. In case none of these advantages are realized, there will be no particular advantage in adding new forms of brake.

External=Contracting Brakes. This class of brakes is divided nto but two types, viz, single- and double-acting. In the first, an end of a simple band is anchored at some external point, while the other, or free end, is pulled. This results in the anchorage sustaining as much pull as is given to the operating end, that is, all pull is transmitted directly to the anchorage. This disadvantage has resulted in this form becoming nearly obsolete.

Any brake of the true double-acting type will work equally well acting forward or backward. The differential brake, Fig. 465, shows this clearly. The external band is hung from the main frame by means of a stout link which is free to turn. The band itself is of very thin sheet steel, lined with some form of non-burnable belting. The ends carry drop forgings, to which the operating levers are attached. These are so shaped that the pull is evenly divided between the two sides of the band. This will be made apparent by considering that a pull on the lever *H* will result in two motions, neither one complete, since each depends upon the other. First, there will be a motion of the upper band end *B* about the extremity of the lower one as a pivot, followed by a movement of the lower end, pivot and all, about *B* as a second pivot point. These two motions result in a double clamping action which is supposed to distribute evenly over the surface. In order to insure even distribution, the lining is grooved, or divided, into sections.

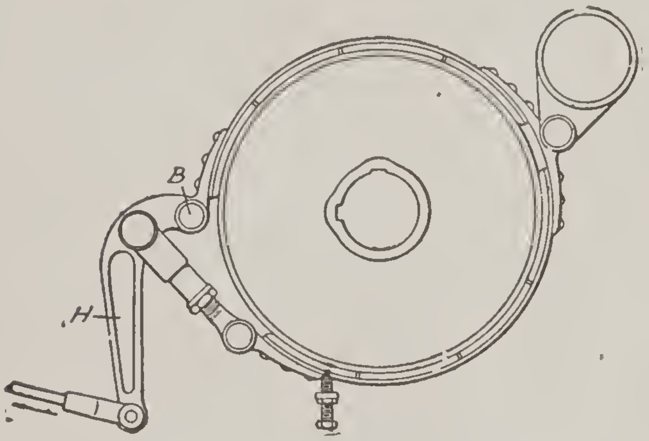


Fig. 465. Brake on Main Shaft of Benz (German) Car

Usually, chain-driven cars have a different brake location from a car with shaft drive. The chain-driven cars have three sets of brakes: one on the main shaft, one pair on the countershaft, and another pair on the rear wheels, as shown in Fig. 466.

Internal-Expanding Brakes. While the contracting-band brake is well thought of, the internal-expanding form is rapidly displacing it, for the reason that experienced drivers think more of it. In Fig. 467 will be seen a modern form of the internal brake, namely, the use of both brakes as internal, but placed side by side in the same drum. This is a tendency which seems to be gaining in favor. The car is the Owen Magnetic, one of the most expensive and luxurious; so the use of side-by-side internal brakes here must be attributed to superiority rather than to a desire to save in money or in parts.

A considerable number of foreign cars, which are used in mountainous countries, show a method of cooling the brake drums by means of external cooling flanges. In some makes, even a water drip is provided for extremely hilly country.

More modern practice shows no tendency to place all of the eggs in one basket, both forms of brake being employed together and upon the same car, usually also upon the same brake drum, one set working upon the exterior, while the other works upon the inside. In Fig. 468, which shows the rear-axle brakes of the larger cars made by the Peerless Motor Car Company, this mechanism is plainly illustrated, both the brakes being shown, although the drum upon which they work has been removed. The parts are all named so as to be self-explanatory. In this construction, the inner, or expanding, band is operated by a cam. In the brake sets put out by the Timken Roller Bearing Company, of Detroit, Michigan, in connection with their bearings and axles, the toggle action is used, Fig. 469. The constructional drawings, Figs. 470 and 471, showing the brakes used on the Reo car, manufactured by the Reo Motor Car Company, of Lansing,

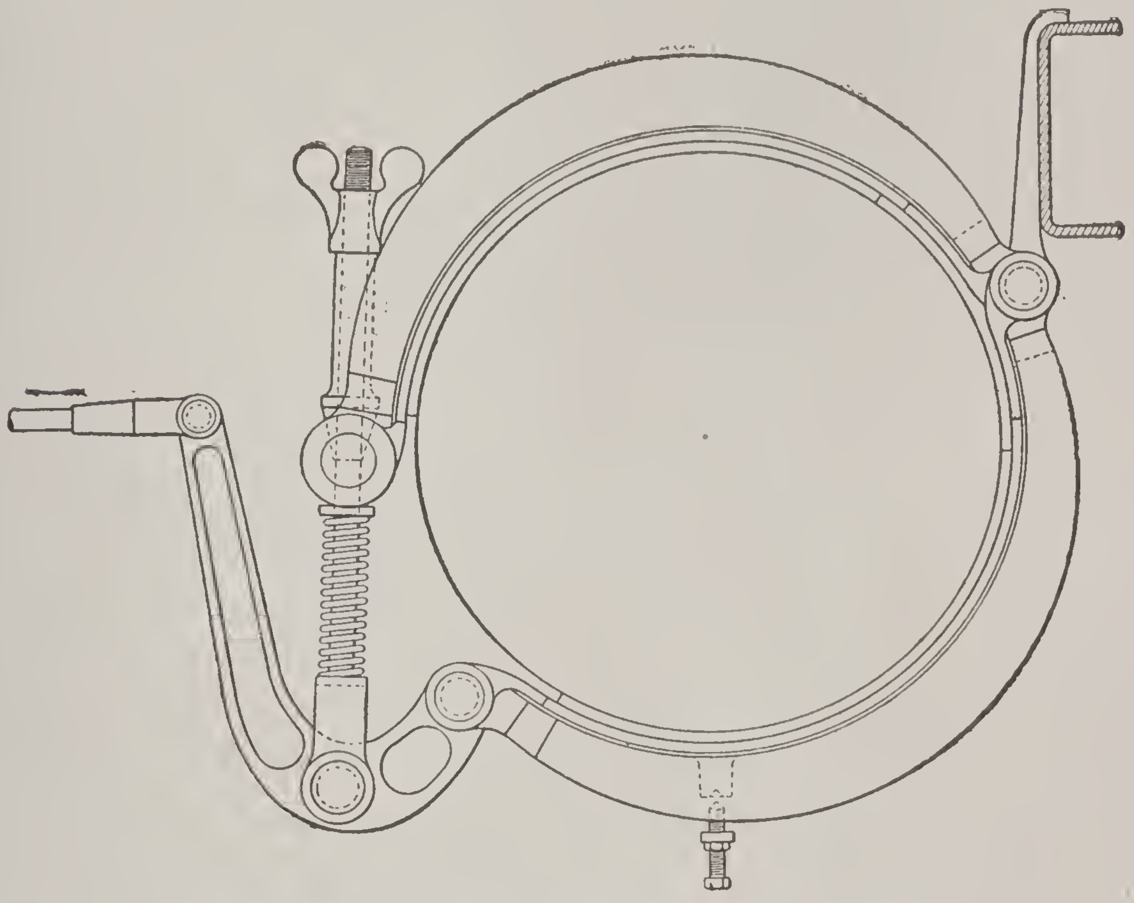


Fig. 466. Benz Countershaft Brakes for Chain-Driven Car

Michigan, indicate that this firm is partial to the cam for brake operation, since these are used for both internal and external brakes, the

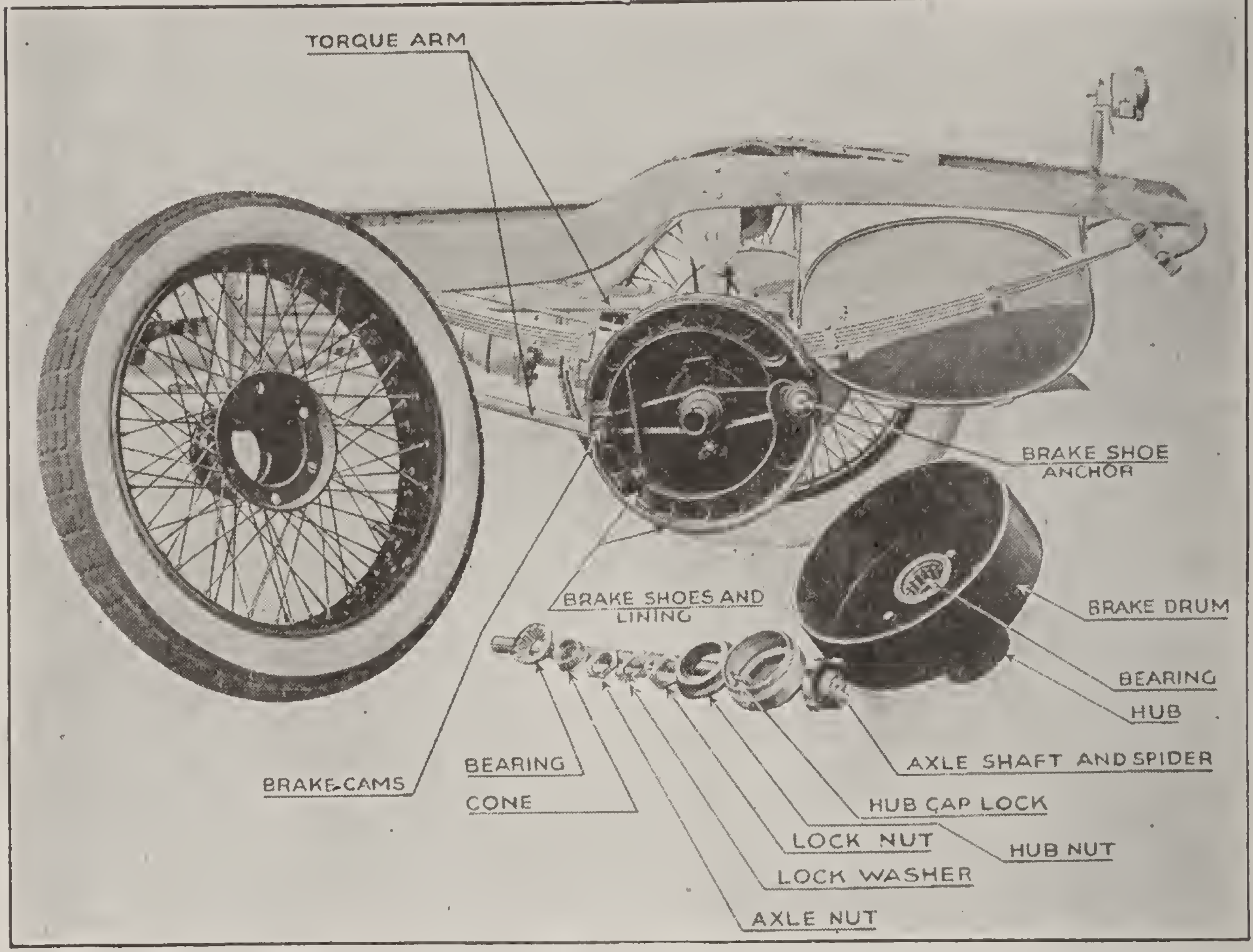


Fig. 467. Rear Axle of Owen Magnetic Car with Wheel Removed to Show Brakes
Courtesy of Baker-R & L Company, Cleveland, Ohio

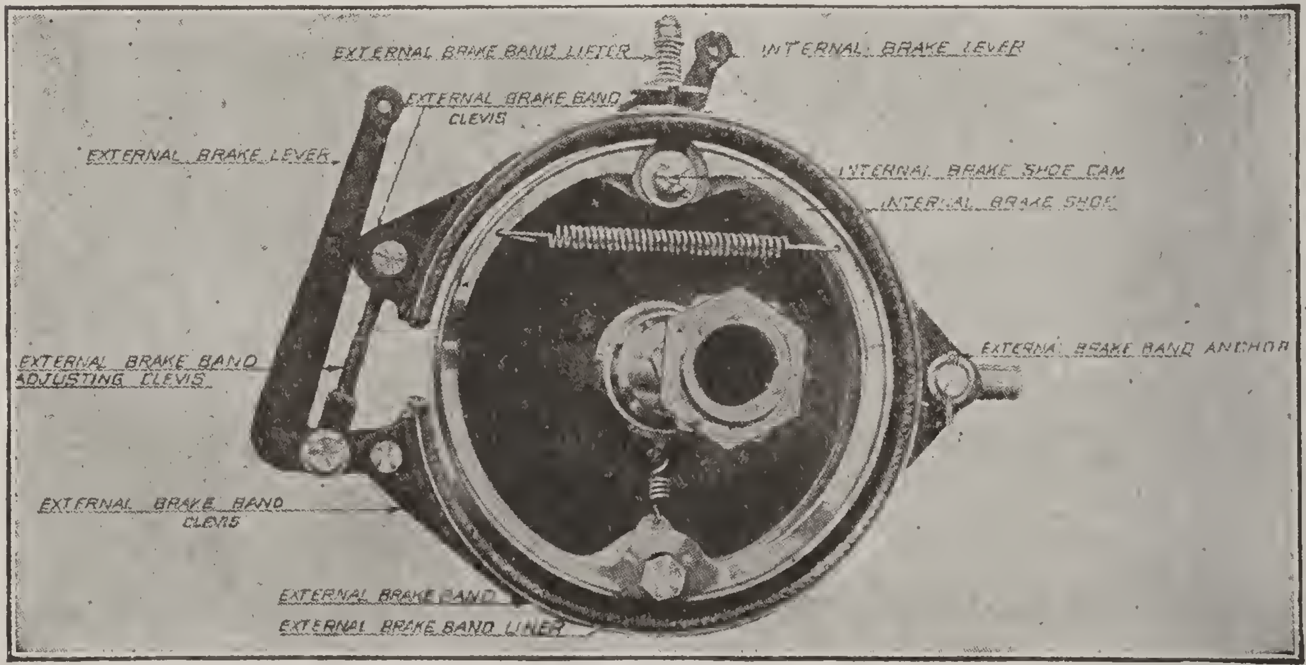

EXTERNAL BRAKE BAND LIFTER
INTERNAL BRAKE LEVER
EXTERNAL BRAKE BAND CLEVIS
EXTERNAL BRAKE LEVER
INTERNAL BRAKE SHOE CAM
INTERNAL BRAKE SHOE
EXTERNAL BRAKE BAND ANCHOR
EXTERNAL BRAKE BAND ADJUSTING CLEVIS
EXTERNAL BRAKE BAND CLEVIS
EXTERNAL BRAKE BAND
EXTERNAL BRAKE BAND LINER

Fig. 468. Peerless Rear-Axle Brake

internal form having a split link connected to the toggle, while the external has a link movement in contracting much like that shown in Fig. 465, which is there explained in detail.

In general, however, when both brakes are placed on the rear wheels, one external and of the contracting-band type, and the other internal and of the expanding-shoe form, modern practice calls for a cam to operate the latter, operating directly upon the ends of the two halves of the shoe, while levers operate the band so as to get a double contracting motion.

Some modern brakes may be seen in Figs. 472, 473, and 474. The first shows a system such as just described; the second shows a stiff metal shoe in both types; and the last a pair of shoes set side by side. In addition, the last-named includes a new thought in that the brake shoes are floated on their supporting pins, as shown. This makes the bearing of the shoes certain when expanded against every portion of the drum, as the shoes can "float" until they fit exactly.

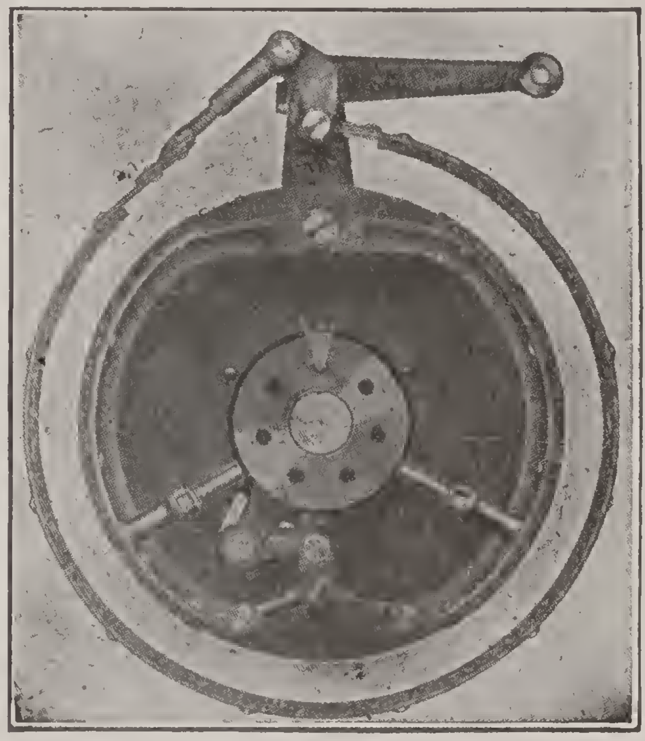


Fig. 469. Timken Double Rear-Axle Brake

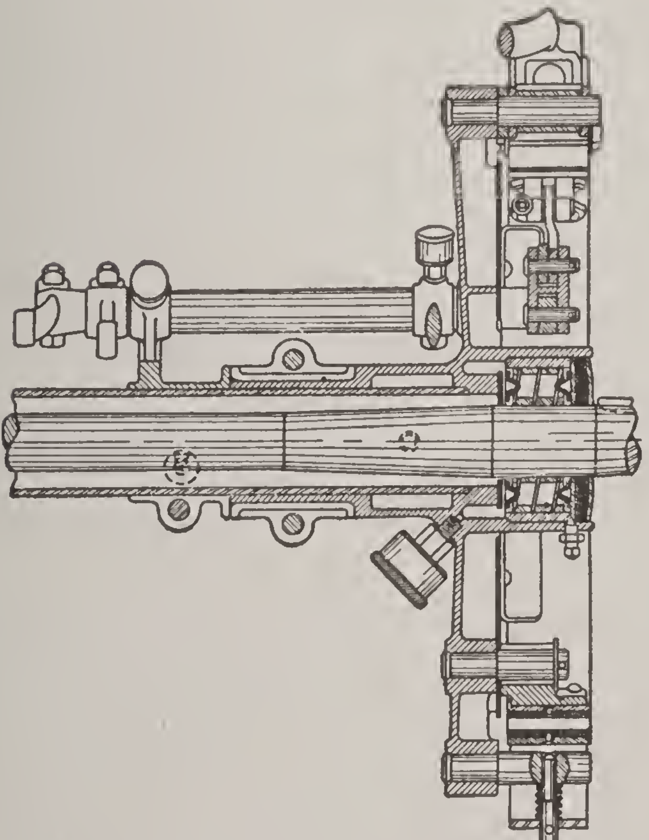


Fig. 470. Section Showing Construction of Reo Brakes

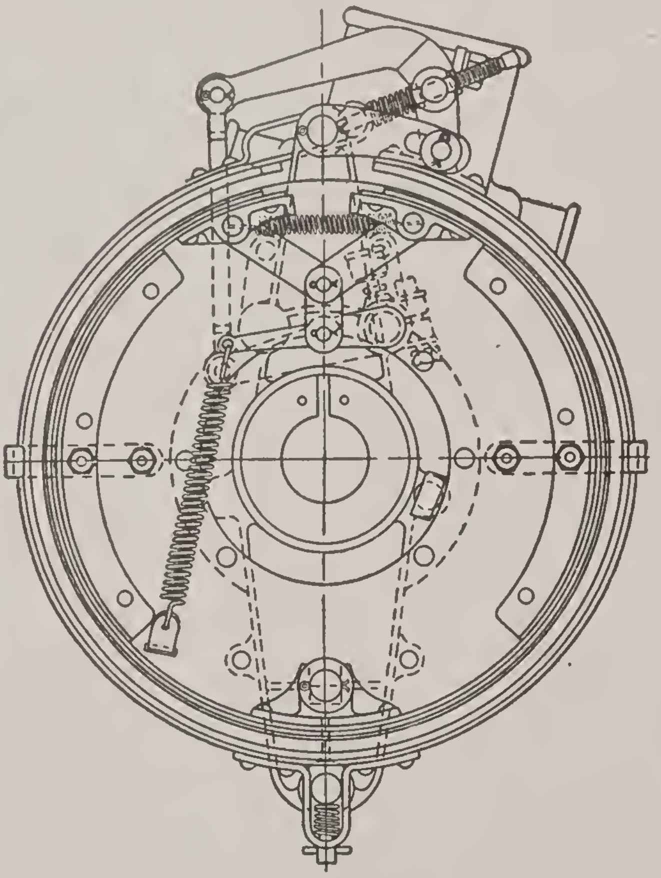


Fig. 471. Drawing Showing Method of Operating Reo Brakes

Courtesy of Reo Motor Car Company, Lansing, Michigan

Double Brake Drum for Safety. A very important feature is pointed out in Fig. 472, namely, that of safety. Where both brakes work on a common drum, one inside and the other outside, the continuous use of the service brake (whether internal or external) heats up the drum to such an extent that when an emergency arises calling for the application of the other brake it will not grip on the hot drum, being thoroughly heated itself. The double drum allows air circulation and constant cooling.

Methods of Brake Operation. While it is generally thought that round iron rods are the universal means of brake operation, such is not the case. Many brakes on excellent cars are worked, as the illustrations show, by means of cables. This idea is even carried so far that brakes have been fitted to operate through the medium of ropes. Chains of small diameter have also been used, as well as combinations of rods, chains, cables, and ropes.

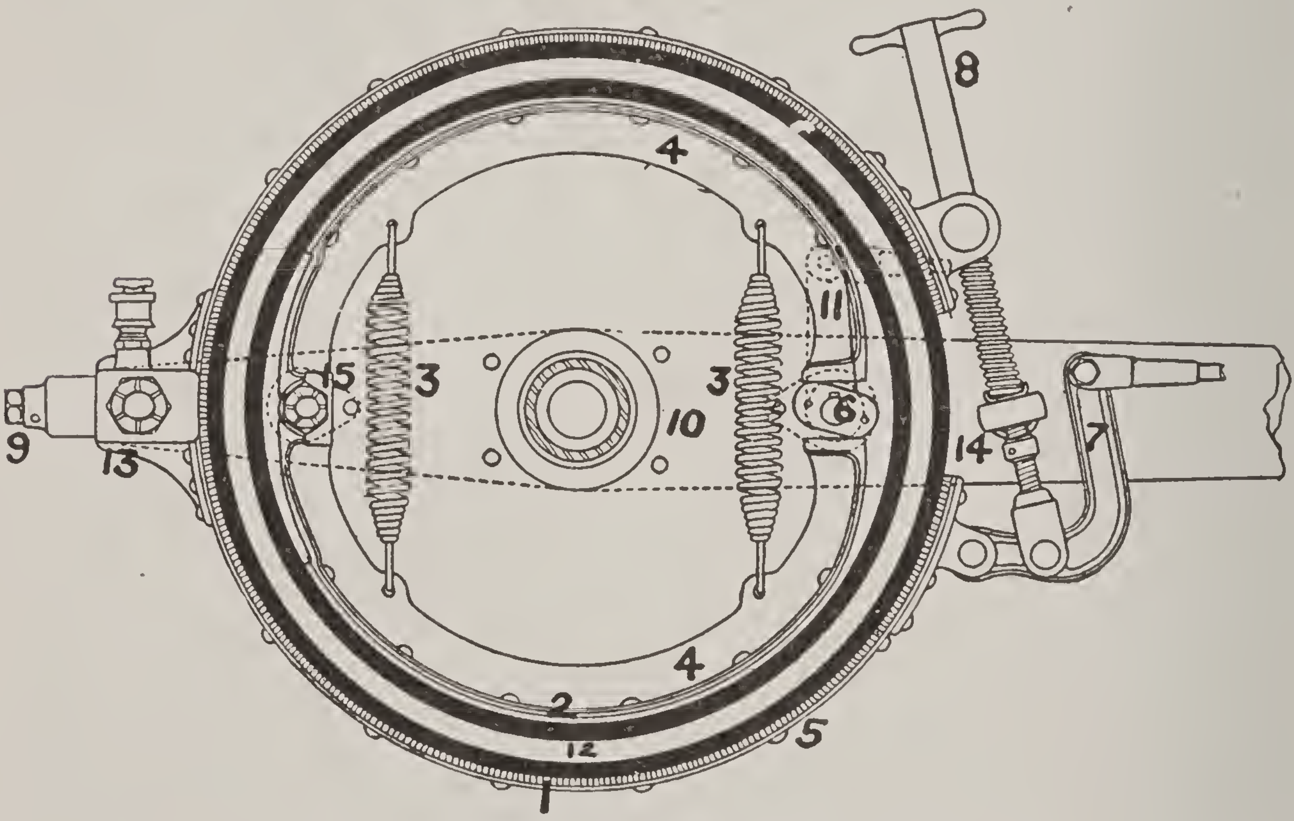


Fig. 472. Double Brake Drum Used on Locomobile Cars

A lever-operated braking system of a well-known medium-priced car is shown in the outline sketch, Fig. 475. In this system the forward part of each half is worked by rods moved by means of pedals, but the rear part of each half is actuated by means of cables. Cables have one advantage over rods in a situation like this—the diagonal pull with a stiff rod might, in time, act to pull the brakes side-

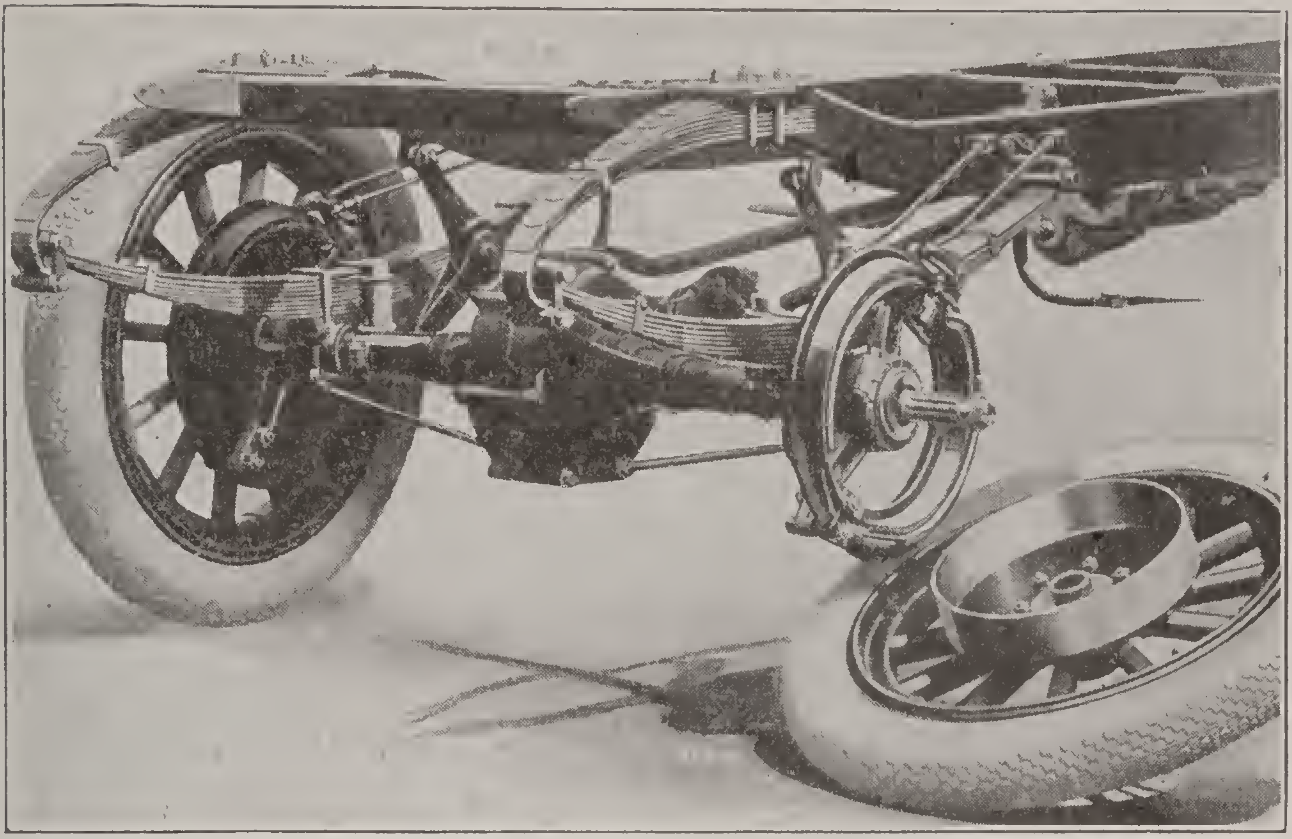


Fig. 473. Brakes and Rear Construction of Pierce Cars
Courtesy of Pierce-Arrow Motor Car Company, Buffalo, New York

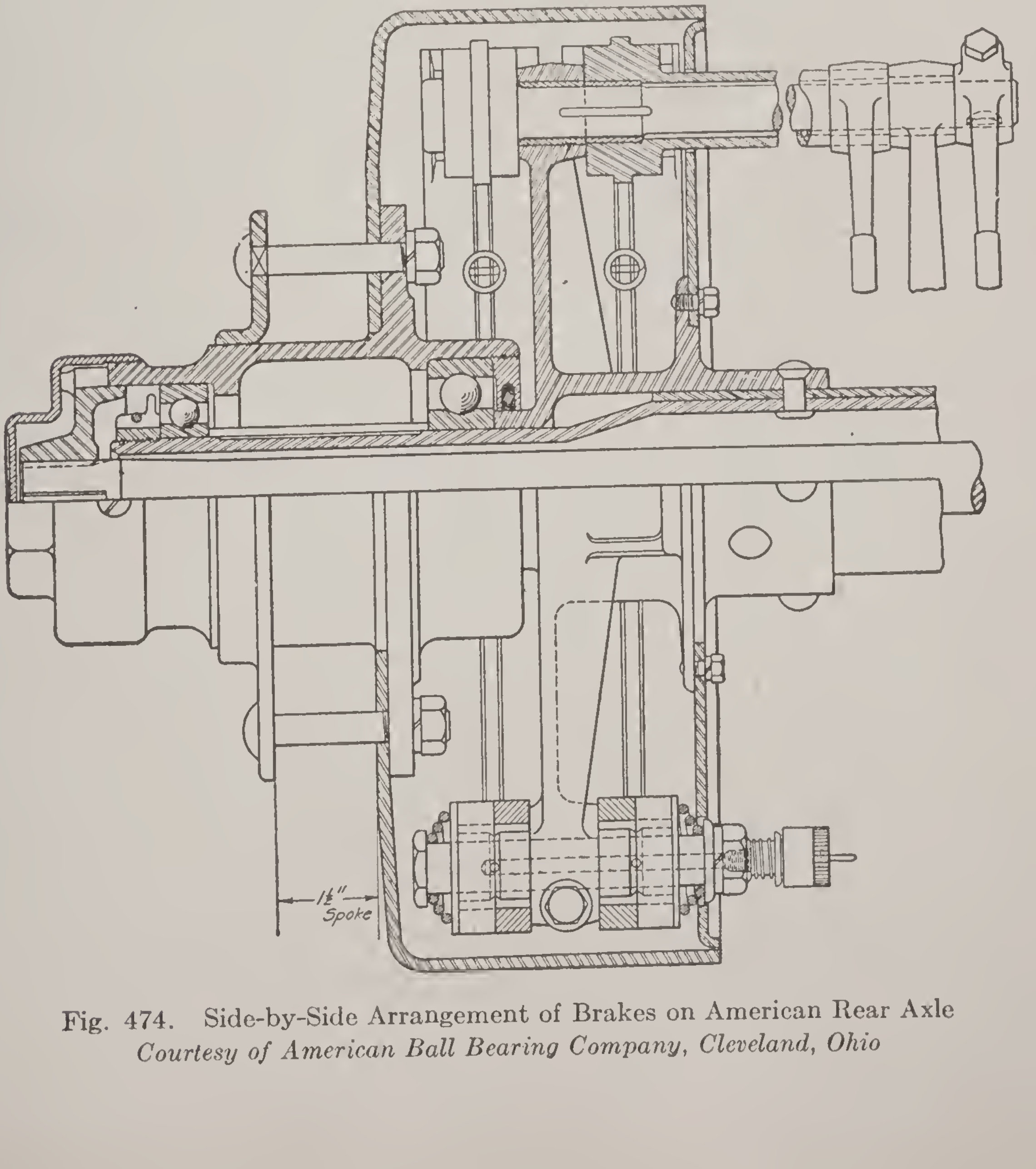


Fig. 474. Side-by-Side Arrangement of Brakes on American Rear Axle
Courtesy of American Ball Bearing Company, Cleveland, Ohio

wise off their respective brake drums, the cable, being more flexible, gives less danger of this.

This method of operation seems to be gaining favor because of its simplicity, which eliminates parts that add weight and gives immediate results when the parts are properly adjusted. The recent New York show revealed a surprising number of small and medium size cars with cable-operated brakes. An inspection of these cars showed a mechanical cleanliness which was lacking in many others of the same class on which an attempt was made to reduce braking rods and levers to a minimum, with consequent bent levers, bent or crooked rods, brakes worked from an angle, and other unmechanical ideas.

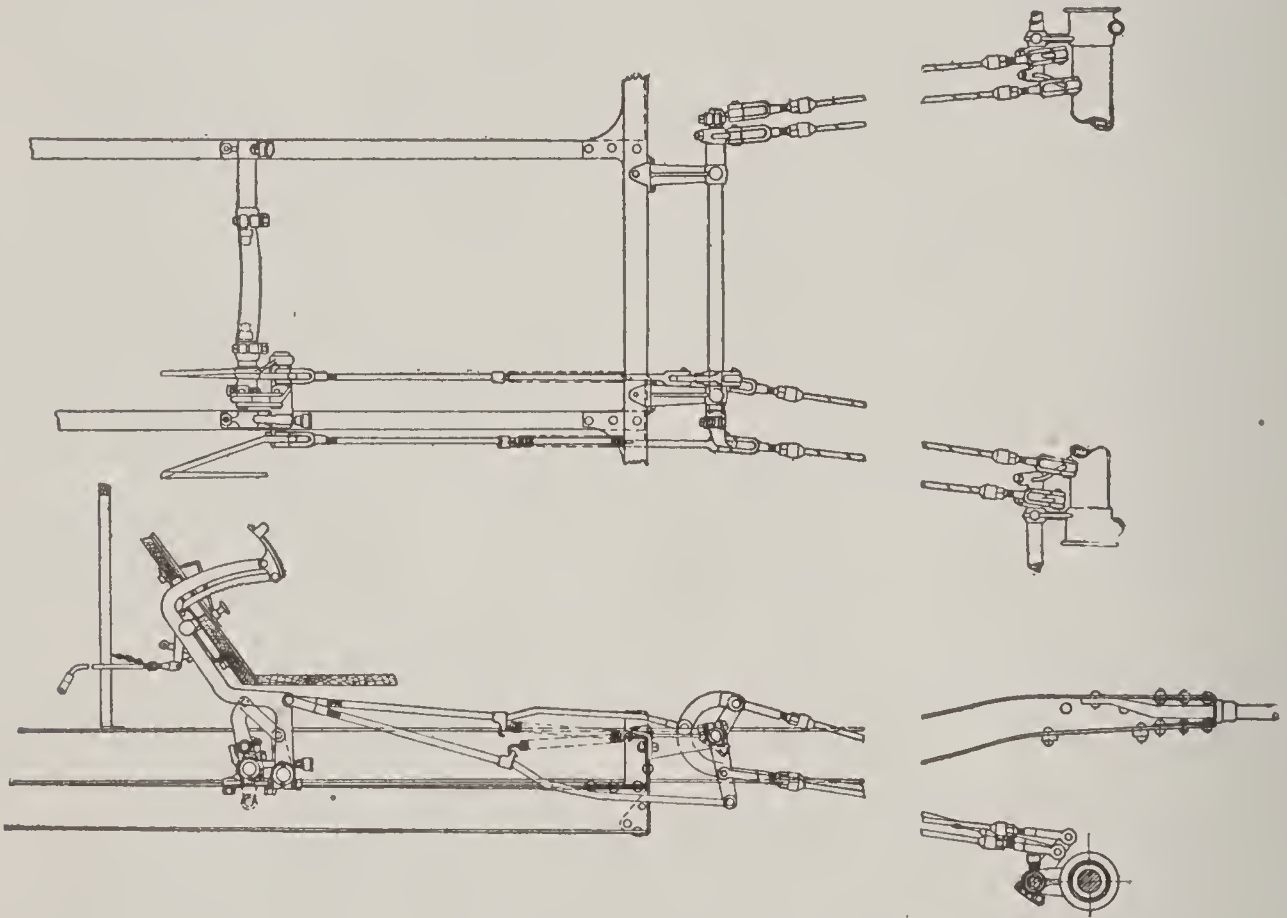


Fig. 475. Layout of Brake-Operating System Using Cables

Fully as important as the operating means is the matter of equalizing the pull so that the same force is exerted upon both wheels at once. This action is influential in causing side-slip or skidding, which may result fatally. To equalize the force was one reason for the use of cables, although the more up-to-date way is to attach the operating lever to the center of a long bar, to the extremities of which the brakes themselves are fastened. A pull on the bar is then divided into two different pulls on the brakes, the division being made automatically and according to their respective needs. This is an important point, and one that should be looked after in the purchase of a new car.

Brake Adjustments. In recent years much of the brake improvement has been that of making adjustments easier and of making the adjusting parts more accessible. This can be noted in such a case as the Locomobile, Fig. 472, where the special adjusting handle on the brake is carried to such a height as to make the turning of it an easy matter. Similarly, on the Pierce, Fig. 473, it will be noted that there is provision for increasing or decreasing the closeness of the shoes to the drum, which is easily accessible.

Brake Lubrication. As for the actual brake surfaces, there is no such thing as lubrication. The surfaces should be kept as dry and clean as possible. If grease or oil gets out from the axle or other lubricated parts onto them, there is sure to be trouble. The operating rods and levers, however, should have fairly careful lubrication, for which purpose the best makers provide grease or oil cups at all vital points. If these be neglected, a connection may stick, so that when an emergency arises the brake will not act properly and an accident may result.

Recent Developments. In the last few years, the only new ideas advanced in the way of brakes concern front-wheel braking and electric brakes. The former were used quite extensively abroad in 1913, but in 1914 they seemed to drop back; this, too, despite the fact that the Grand Prix race of the latter year showed in a marked manner the need for and special application of front-wheel brakes to racing and high-speed cars.

Electric Brakes. A very efficient and compact brake, applicable with a small amount of work to any chassis having a storage battery, is the Hartford, shown in Fig. 476, while Fig. 477 shows the operating lever as it is placed beneath the steering wheel, and Fig. 478 shows the wiring system. This brake consists, in substance, of a small reversible electric motor, to which a 100 to 1 worm reduction is attached. Attached to the drum is a cable, which is fastened to the usual brake equalizer. Turning the current into the motor from the storage battery rotates the drum, winds up the cable, and applies the brake. The complete outfit weighs but 35 pounds. The motor has a slipping clutch set to operate at 1000 pounds pull, at which it draws 40 amperes of current from the battery for two-fifths of a second.

In use, it replaces the emergency hand-operating lever, and is said to be able to pull a heavy car going 50 miles an hour down to less than 15 in a distance of less than 35 feet. The pull is so great that the brake drums are oiled to prevent heating and possible seizing.

Hydraulic Brakes. On the newer Knox tractors, a brake of very large size is made even more powerful by hydraulic operation. This brake is shown in Fig. 479. At the left will be seen the usual brake lever attached to a small piston in a chamber full of liquid. This chamber communicates through the medium of a valve normally held closed by a spring, with a passage above, and that, in turn, communicates with the pipes leading to the brake-operating cylinder. This cylinder has a stout rod attached to a good size plunger, back of which the liquid (oil) is introduced. When liquid is forced in, the plunger moves forward, forcing the rod out and, through connecting rods and levers, applying the brakes. As will be seen in the drawing at the right, these brakes, which are of the

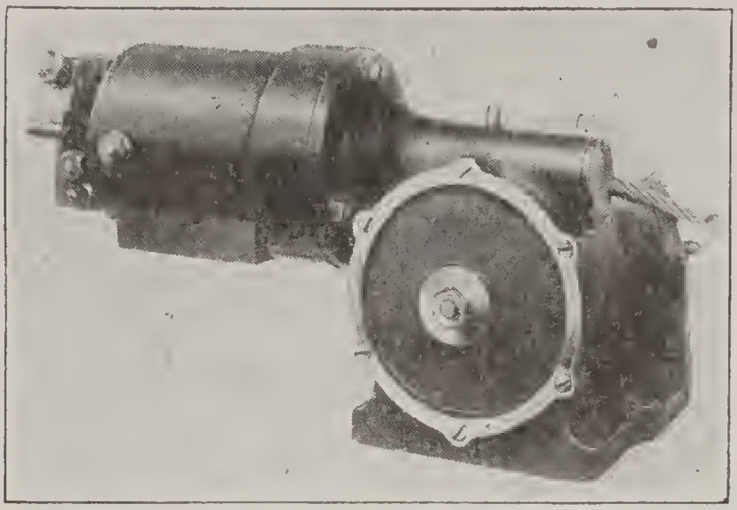


Fig. 476. Exterior of Motor Which Forms Central Unit of Hartford Electric Brake
Courtesy of Hartford Suspension Company, Jersey City, New Jersey

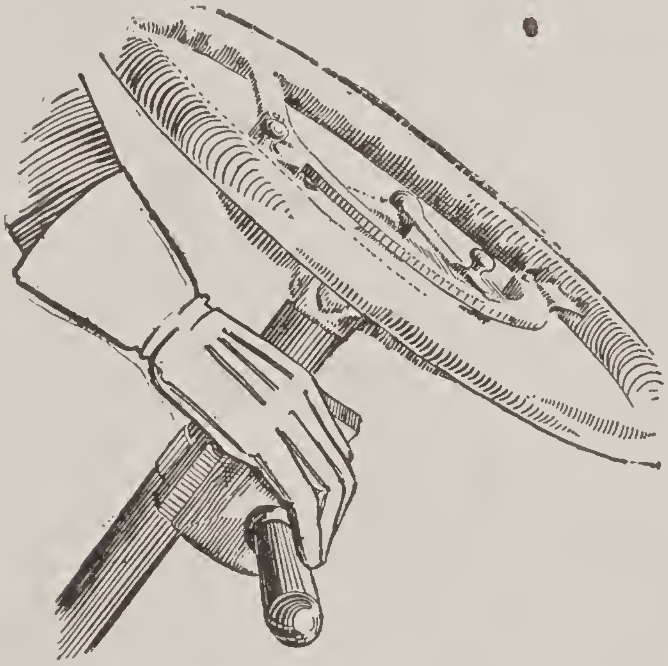


Fig. 477. Hand Lever on Steering Post for Operating Hartford Electric Brake

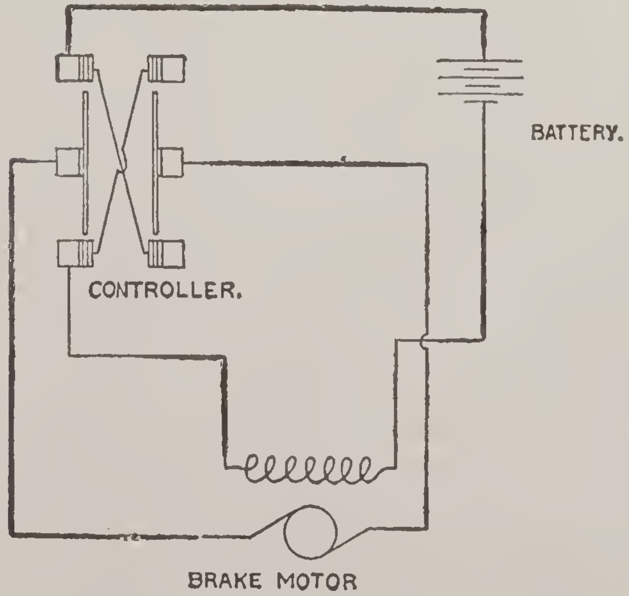


Fig. 478. Wiring Diagram for Hartford Electric Brake

internal-expanding type, are exceptional in size and work against steel drums attached directly to the wheel spokes.

When the lever is drawn back in the usual manner, liquid is forced upward through the top passage to and through the pipes into the other cylinder, forcing the plunger to move, and, through the movement of the plunger, the brakes are applied. The return of the fluid is not shown, but it is assumed that this is through a simple pipe connection from the plunger cylinder to the hand-operated piston with a check valve. Should the initial movement of the lever fail to apply the brakes sufficiently, the driver can let the lever come forward and then pull it back again; in so doing he will take into his lever cylinder more liquid from below without releasing the brakes. Then, when this extra quantity is forced through, the plunger is moved even farther forward, and the brakes applied more forcibly. The brakes are 20 inches in diameter by 6½ inches wide.

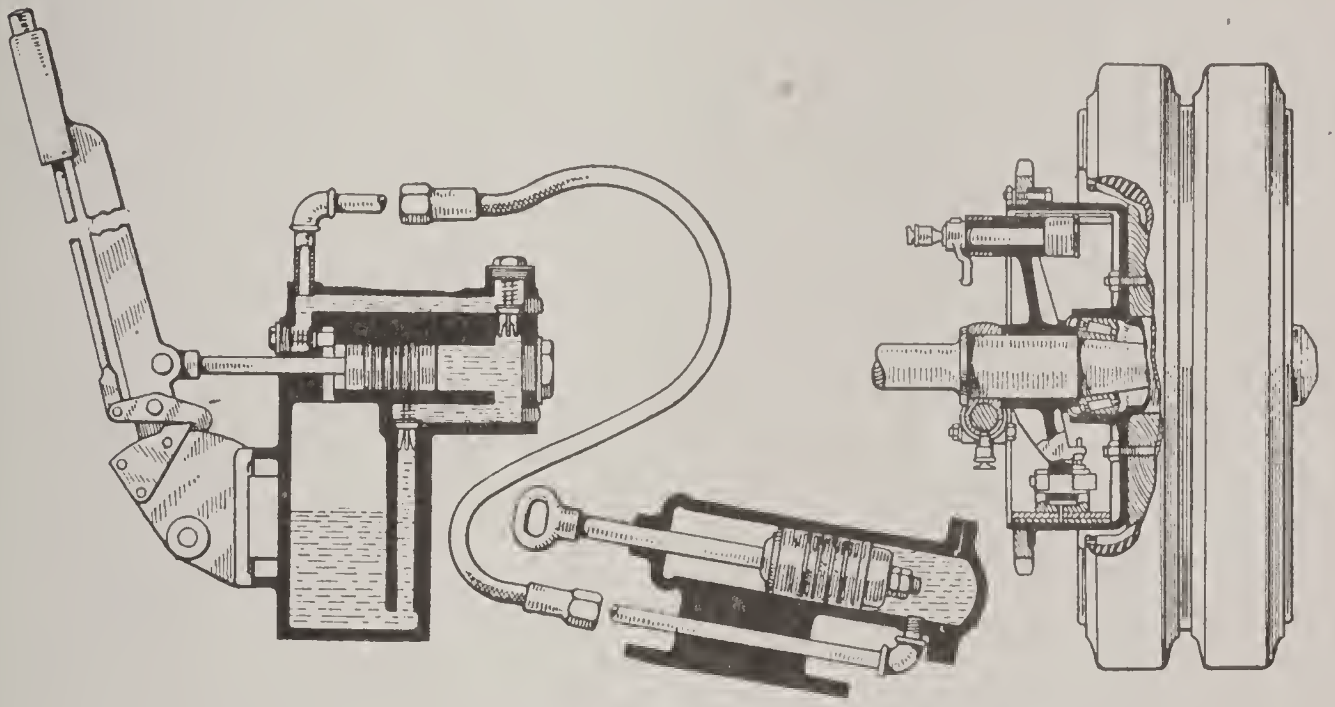


Fig. 479. Layout of Hydraulic Brakes Used on Knox Tractor
Courtesy of Knox Motors Company, Springfield, Massachusetts

Vacuum Brakes. The latest development in the line of braking systems is the Prest-O-Lite vacuum brake. This brake consists of a controlling valve, a vacuum chamber, piping from the inlet manifold to the valve and thence to vacuum chamber, and a foot button or finger lever on the steering post to operate the valve and thus put the system into use. The rod in the vacuum chamber is connected up to the service brakes, the system thus taking the place of the usual pedal and foot operation. The chassis sketch, Fig. 480, shows this in plan, *A* being the controlling valve, *BB* the tubing from the inlet manifold to the controlling valve and from it to the vacuum chamber *C*. The rod *D* from the chamber will be seen connected to the service-brake rods and levers.

In Fig. 480 the method of operating the system is not shown, but in Fig. 481 the foot lever can be seen with its connections. When this is pressed, the controller valve is opened and the engine, as it runs, draws air out of the chamber *C* in back of the plunger, gradually creating a vacuum, so that the plunger is forced to move forward to compensate for this. As the plunger carries a tail rod projecting through the end of the cylinder, and as this rod is connected up to the braking system, but with a big leverage, the movement of the plunger applies the brakes. The amount of brake application depends upon the amount of suction, and that is governed by the amount the valve is opened by the finger lever or foot button. Consequently, with this new brake, the bucking effort can be varied to suit the conditions.

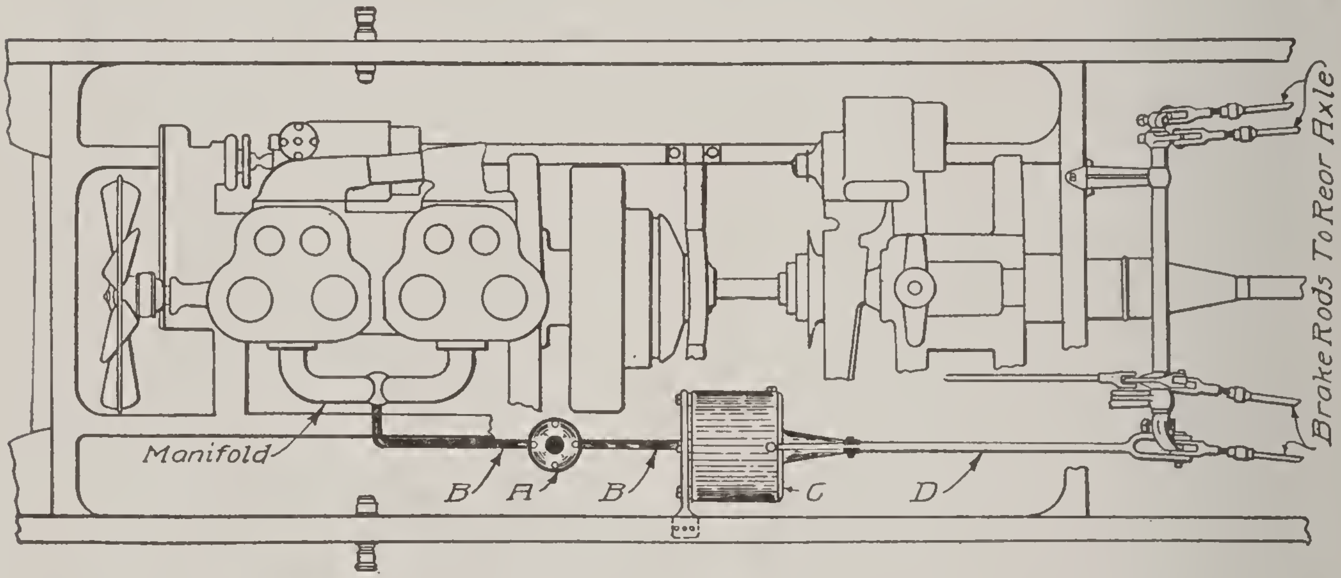


Fig. 480. Chassis Plan Showing Application of Prest-O-Lite Vacuum Brake
Courtesy of Prest-O-Lite Company, Indianapolis, Indiana

It is said that the leverage arrangement is such that 10 pounds per square inch in the intake manifold will produce 1000 pounds braking effort at the rear wheels. This means that the brakes could be used with the engine running very slowly. The system is applied to the service brakes because a brake is sometimes needed when the engine is not running, as when coasting down a hill with the engine shut off and clutch out, or with the car standing and engine shut off, etc.; also because it is the most used system, and it is felt that the simple finger pressure and gradual or instantaneous application possibilities of the new form make it more desirable as a service or running brake.

Whatever advantages may develop in the use of these special types, it is certain that the next few years will see considerable improvement in braking, so that a greater force may be applied more quickly, and thus act to prevent a large part of the accidents for which automobile owners and drivers are now unjustly blamed.

BRAKE TROUBLES AND REPAIRS

Dragging Brakes. Probably the first trouble in the way of brakes is that of dragging, that is, braking surface constantly in contact with the brake drum. This should not be the case, as springs are usually provided to hold the brake bands off the drums. Look for these springs and see if they are in good condition. One or both of the brake bands may be bent so that the band touches the drum at a single point.

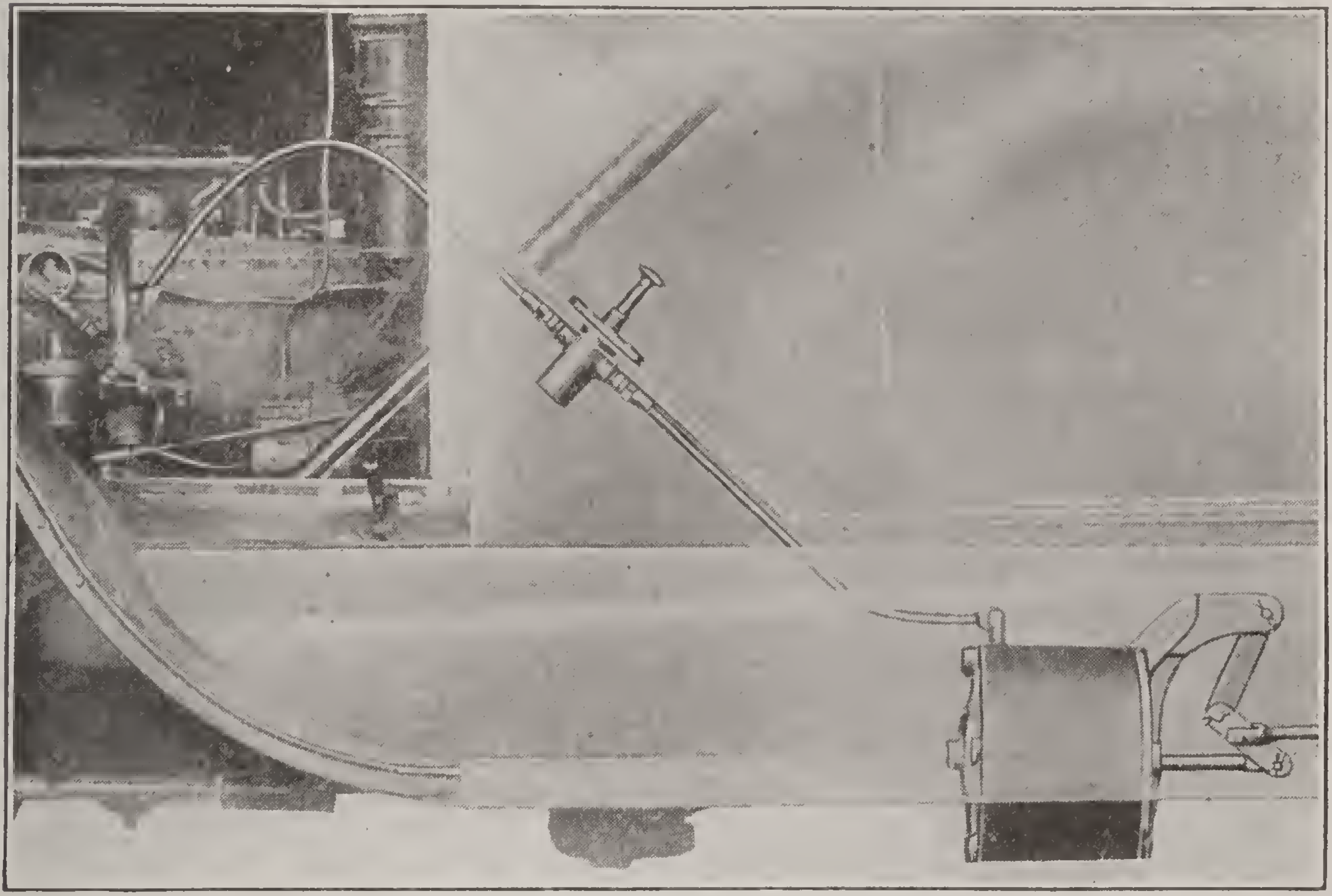


Fig. 481. Foot Button for Operating Vacuum Brake

Another kind of dragging is that in which the brakes are adjusted too tightly—so tightly, in fact, that they are working all the time. In operating the car, there will be a noticeable lack of power and speed, while the rear axle will heat constantly. This can be detected by raising either rear wheel or both by means of a jack, a quick lifting arrangement, or a crane, and then spinning the wheels. If the brakes are dragging, they will not turn freely.

All that is needed to remedy this trouble is a better adjustment. For the new man, however, it is a nice little trick to adjust a pair of brakes so that they will take hold the instant the foot touches the pedal, that they will apply exactly the same pressure on the two wheels, and yet will not run so loose as to rattle nor so tight as to drag.

Dummy Brake Drum Useful. Where a great deal of brake work is to be done, particularly in a shop where the greater part of the cars are of one make, and the brakes all of one size, a great deal of time and trouble can be saved by having a set of test drums. An ordinary brake drum with a section cut out so that the action inside may be observed is all that is necessary, except that it should be mounted suitably. As shown in Fig. 482, it is well to fit a pair of handles to the brake drum to assist in turning the drum when the adjustment is being made. The real saving consists of the work which is saved in putting on and taking off the heavy and bulky wheel each time when the adjustment is changed. The test drum is put on instead, and being small and light and equipped with handles, it is easily and quickly lifted on and off. This enables the workman to make a better and more accurate adjustment than he would when the heavy wheel had to be handled, while the cut-out section enables him to see the inside working also and thus correct any defects or troubles at this point.

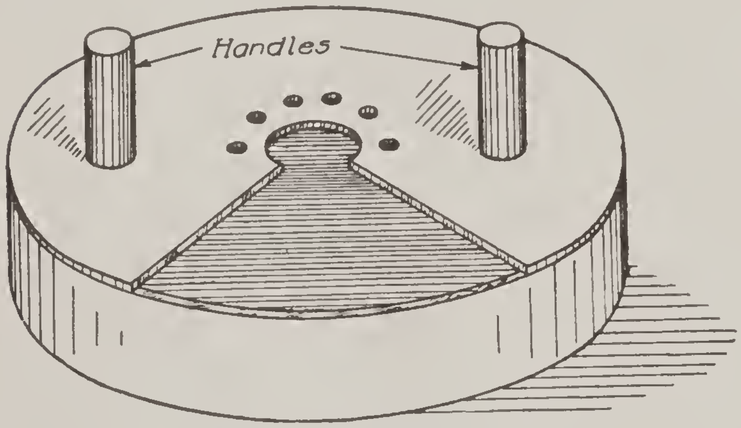


Fig. 482. Dummy Brake Drum for Adjustment Work

To Stop Brake Chattering. It is claimed that the chattering of brakes is caused by having the brake lining, particularly of internal hand brakes, extend over too large a portion of the circumference of the drum. The result is that with a well-adjusted system, as soon as force is applied, the lining close to the operating cam and that on the opposite side close to the pin on which the brake shoes are pivoted jumps against the drum and then away from it. This jumping of the brake shoe, which is the result of too much lining, is what causes the chattering. If the lining is cut away for about 30 degrees on either side of a line drawn from cam to pivot pin, as shown in Fig. 483, it is said that this chattering will stop immediately. If further trouble of the same kind results, bevel off the outside ends of the lining at the two 30-degree points.

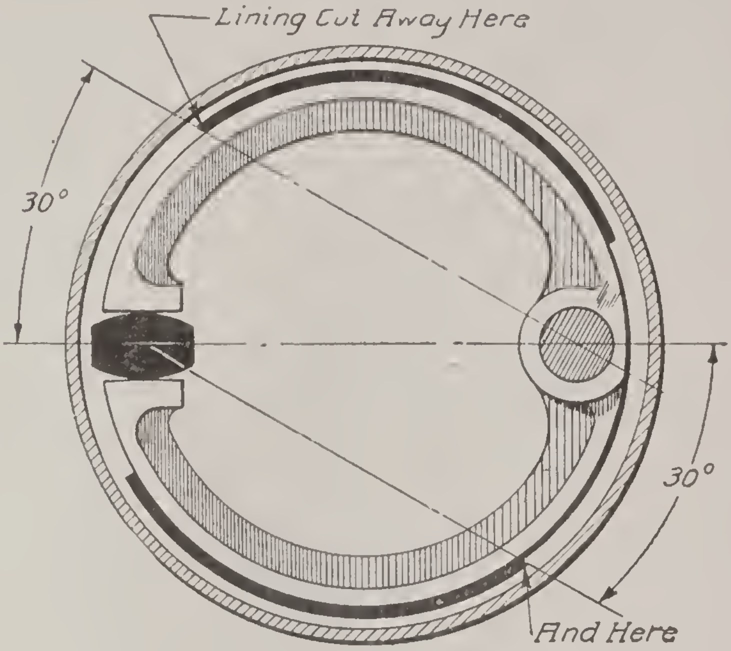


Fig. 483. Method of Eliminating Brake Chattering on Internal-Expanding Brakes

A number of suggestions in the way of possible brake troubles, particularly on the side-by-side form of internal-expanding brakes, are indicated in Fig. 484. This shows a semi-floating form of rear axle with the two sets of brakes and operating shaft and levers. A number of suggestions are offered for this form, the most important of which is: "Renew worn brake lining and broken or loose rivets."

When a brake lining is worn, the proceeding is much the same as with a clutch leather, with the exception that whereas the latter must have a curved shape, the former can be perfectly straight and flat. This simplifies the cutting; but most brake linings are made of special heatproof asbestos composition which is made in standard widths to fit all brakes, so the cutting of leather brake bands is not often necessary.

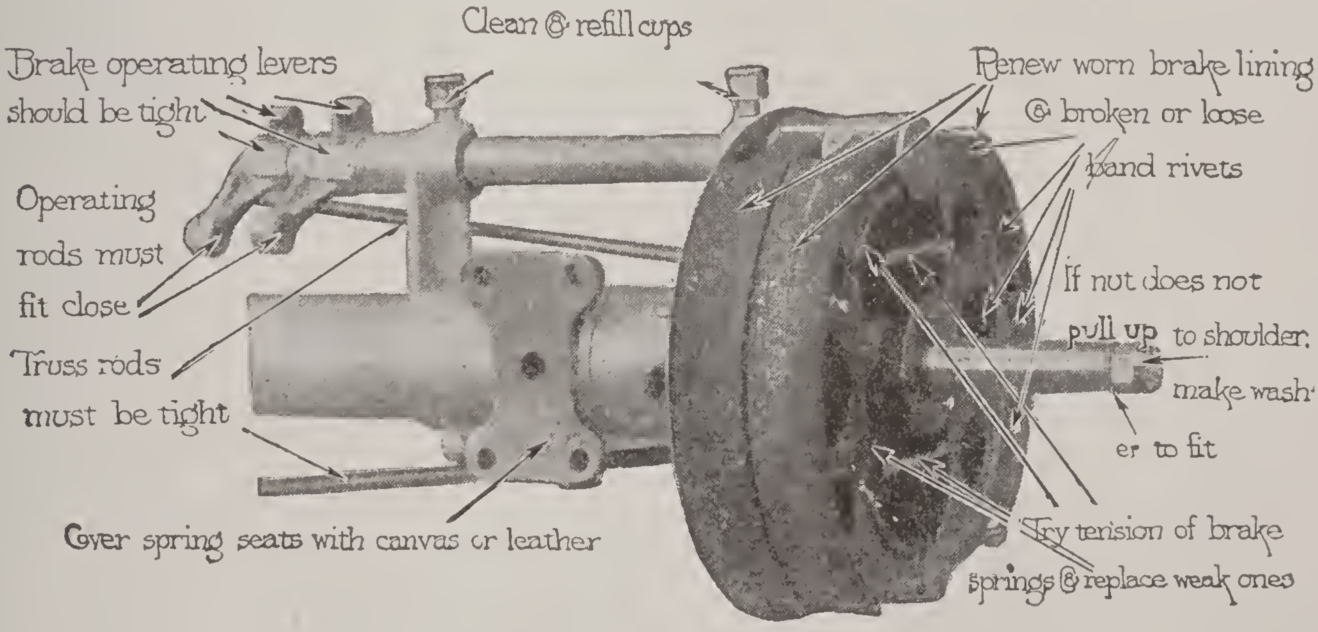

Clean & refill cups
Brake operating levers should be tight
Operating rods must fit close
Truss rods must be tight
Cover spring seats with canvas or leather
Renew worn brake lining & broken or loose band rivets
If nut does not pull up to shoulder, make washer to fit
Try tension of brake springs & replace weak ones

Fig. 484. Brake Troubles Illustrated

Eliminating Noises. Many times the brake rods and levers wear just enough to rattle and make a noise when running over rough roads or cobblestone pavements, but hardly enough to warrant replacing them. The replacement depends on the accuracy with which they work, the age and value of the car, and the attitude of the owner. In a case where the owner does not desire to replace rattling rods, the noise can be prevented by means of springs, winding with tape, string, etc.

If the rod crosses a frame cross-member or is near any other metal part, and its length or looseness at the ends is such that it can be shaken into contact there, a rattle will result at that point. This can be remedied or rather deadened by wrapping one part or the other. For this purpose, string or twine can be used as on a baseball bat or tennis racket handle, winding it together closely so as to make a continuous covering. Tire or similar tape may also be utilized. When this is done, it is necessary to lap one layer partly over the next in order to keep the whole tight and neat. It has the additional advantage of giving a greater thickness and thus greater resistance to wear. If none of these remedies are available or sufficient, burlap in strips or other cloth may be used, putting this on in overlapping layers the same as the tape.

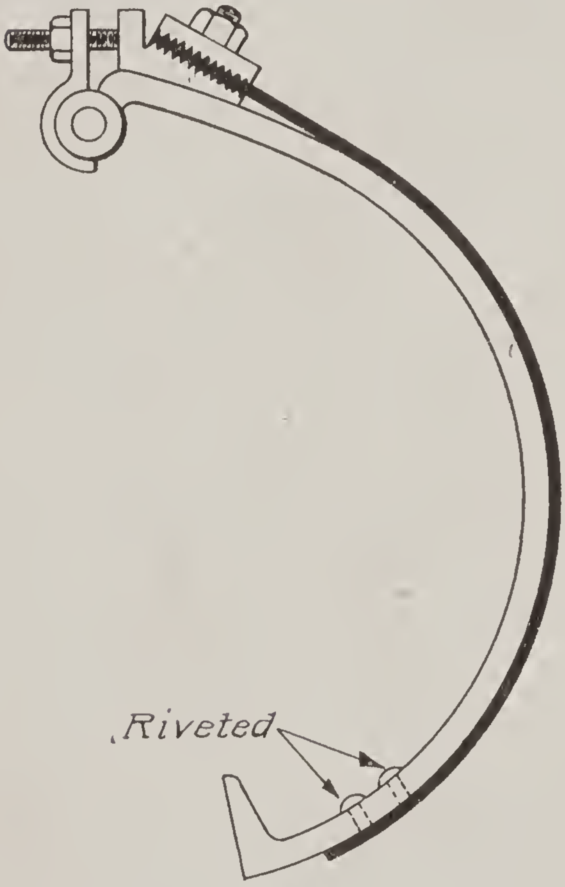


Fig. 485. Sketch Showing Method of Stretching Brake Linings before Attachment
Courtesy of "Motor World"

The springs should be put on in such a way as to take up the lost motion and hold the worn parts closer together. The rattle occurs when the movement of the car alternately separates and pulls together the two parts, a noise occurring at each motion. The spring should be put on so as to oppose this motion, acting really as a new bushing or pin, the pull coming first upon the spring and then upon the bushing or pin.

Stretching Brake Lining. Brake lining should be put on as tightly as possible, and the knowledge of this, combined with the difficulty of doing it by hand, makes the stretching device shown in Fig. 485 particularly valuable when much brake relining is to be done. This is a simple pulling clamp, which is attached to one end of the lining after the first end has been riveted in place. Then it is attached to the end of the shoe, and the nut tightened so as to stretch it. When it has been stretched sufficiently, the other rivets can be put in, or the shoe and band with the stretches in place can be laid aside for a while to stretch it fully before fastening. Obviously, this is applicable only to the internal-expanding form, but the hook and clamp can be used on any size or type of expanding brake.

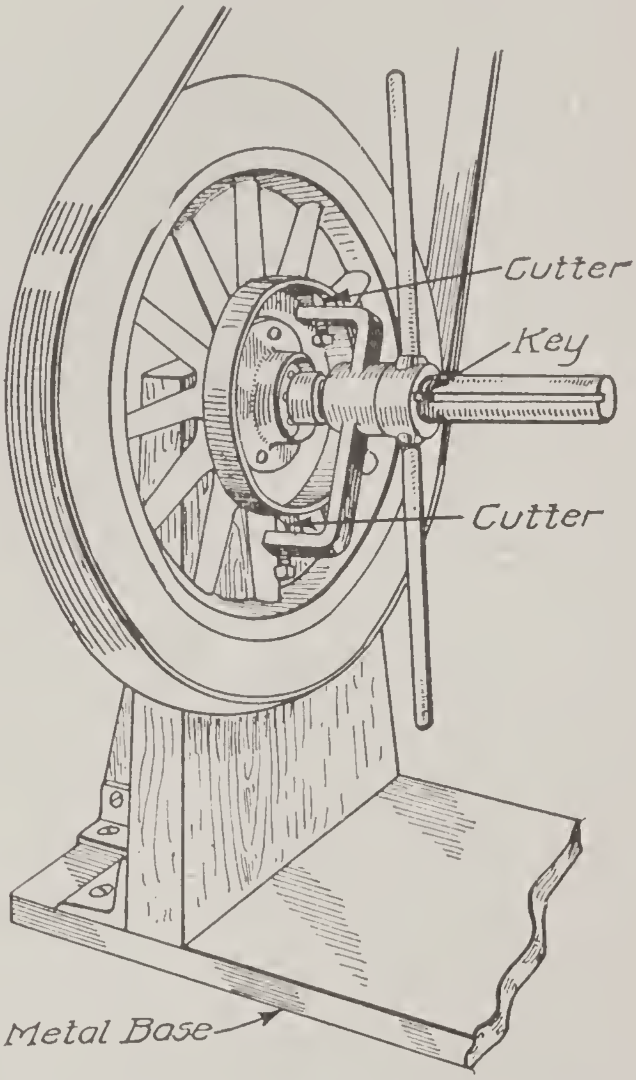


Fig. 486. Apparatus for Truing Inside and Outside of Brake Drum in Place on Wheel
Courtesy of "Motor World"

Truing Brake Drums. When both inside and outside surfaces of the brake drum are used, it is highly important that both be true. Since they do not stay that way long, the repair shop should be equipped to true them up quickly. A truing device is shown in Fig. 486, with the wheel and brake drum in place on it. One feature of the device is that brake drums need not be removed from the wheel. The device consists of a metal base having a strong and stiff wooden pier with a horizontal arm the exact size of the axle end mounted on it. The wheels are placed on the arm and rest on it the same as on the axle when on the car. The tool is double, with two ends, one of which cuts the inside surface of the drum, while the other cuts the outer surface. At the center this tool is attached to a heavy casting, bored out to slide over the shaft and with a key fitted into a keyway in the shaft to prevent the tool from rotating. The end of the arm is threaded, and a large nut with two long arms is screwed up against the tool at the start, and then it is used to feed the latter across the work.

This is subject to a number of modifications to fit it to the various sizes and shapes of brake drum. Another method is to use the lathe, provided the shop is equipped with a lathe large enough. By making a mandrel the same as the axle spindle and having a pair of dummy bearings to place on it, the brake drum can be slipped on to the mandrel, and the whole put right into the lathe. The surface, either internal or external or both, can then be trued up exactly as if the drum were on the axle.

WHEELS

Broadly speaking, there are but two kinds of wheels according to the service each is to render, pleasure-car wheels and commercial-car wheels. The former may be further subdivided into wood, wire, and spring wheels; while the latter may be divided into wood, steel, and spring wheels. Some of the commercial vehicle wheels are further divisible, as steel wheels into sheet steel and cast steel; wood into spoked and solid; and spring wheels into various types.

Wheel Sizes. Wheels are used on automobiles, in combination with the tires, to afford a resilient and yielding contact with the surface of the road, so that people may ride with comfort. Therefore a wheel whose size is such as to yield the most comfort to the car occupants with due regard to its cost relative to the cost of the vehicle is the wheel to use. The cost of the wheels themselves, however, is so small in comparison with the cost of the pneumatic tires which are used on them as to be completely overshadowed by the latter.

Where comfort is sought as the prime requisite, cost becomes an accessory. The larger the wheel used the better the car will ride, and the greater will be the comfort of the occupants. This statement can be proved, although the gradually increasing sizes of wheels and tires as used on the best cars, both here and abroad—advancing from the early 26 and 28×3-inch tires, to as high as 38×5½-inch tires, and freaks up to 48×12-inch—should be sufficiently convincing.

Advantages of Large Wheels. A graphical demonstration of the difference between the action of the large and small wheel to the advantage of the former is shown in two drawings, Figs. 487 and 488. Fig. 487 presents the case of wheels passing over a common brick 4 inches wide by 2 inches high, and Fig. 488 shows the action in passing across a small rut in the surface of the road, 8 inches wide by 1¼ inches deep. In both cases, *A* shows the 28-inch wheel and *B* shows the 40-inch wheel. Both instances, too, have been selected at random, and not so chosen as to favor either wheel. It would have been possible to so select the sizes of both obstruction and depression as to make out a stronger case.

The height of the brick being 2 inches the wheel must rise that distance, whatever its diameter, but in the case of the 28-inch wheel, this rise of 2 inches is largely relative to the wheel diameter being one-fourteenth, or 7 per cent. In the case of the larger wheel of 40-inch diameter, the rise is again 2 inches, but it is now one-twentieth of the wheel diameter, or 5 per cent. In the case of the smaller wheel, the rise is distributed over a length of about 18.43 inches from the moment when the forward edge strikes the obstacle to the moment when the last part of the tire leaves the last edge of the brick. If this rise were evenly distributed over this distance, rising as an arc of a circle, its radius would be slightly over 22 inches.

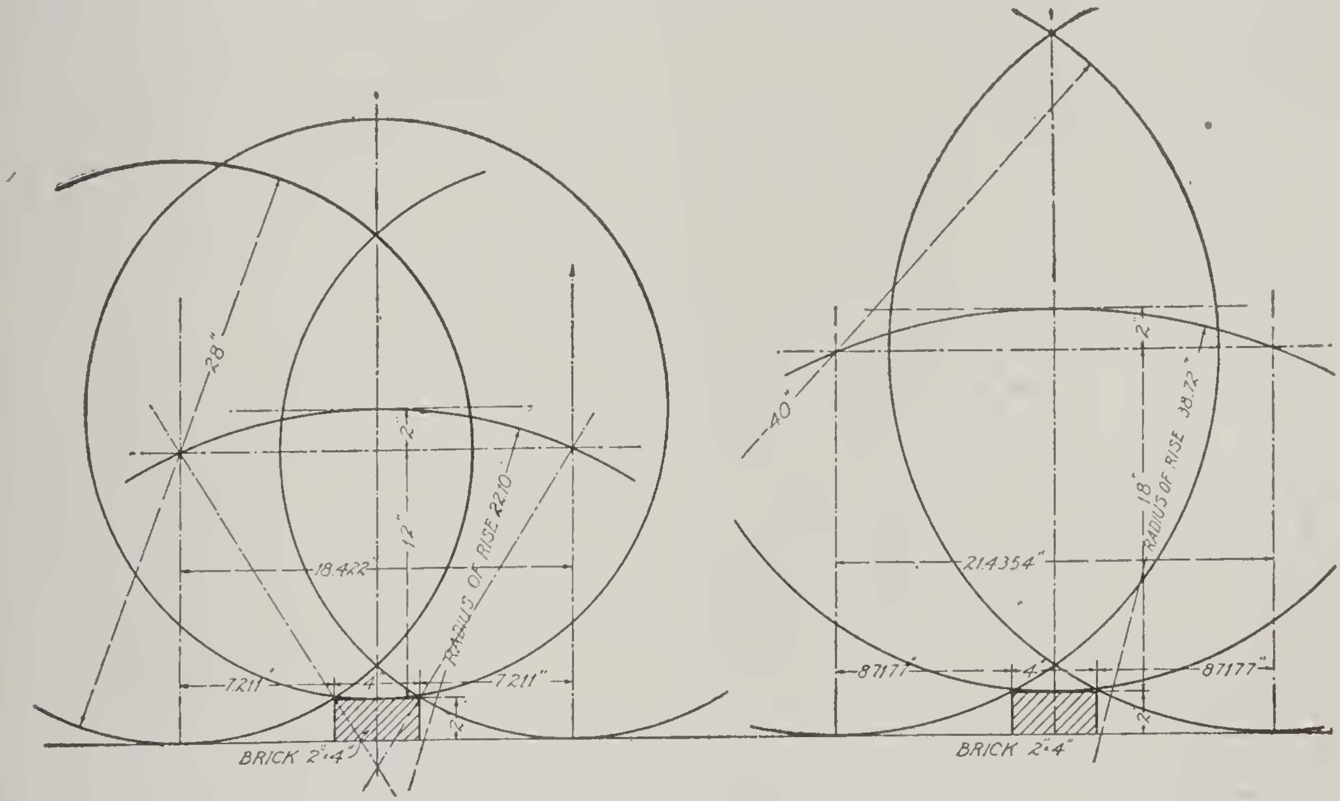


Fig. 487. Diagram Showing Advantage of Large Wheels in Passing over Obstruction

Considering the 40-inch wheel under the same circumstances, it performs the act of rising and falling 2 inches in the longer distance of about 21.5 inches, the radius of this rise being 38.75 inches. It is obvious that the latter is a much easier rise than the former, the lift being distributed over a length 16 per cent greater. Similarly, with the descent from the high point to the surface of the road again, this more gradual rise and fall convert the surmounting of the obstacle from a sharp upward bump and downward jounce into an easy and not unpleasant swinging up and down.

A drop into a hole, as illustrated by Fig. 488, shows the beneficial effect of the large wheel better, perhaps, than does the rolling over a rise. A rut in the road 8 inches across, into which the two wheels drop in passing, is shown. At *A*, the 28-inch wheel is seen to drop the considerable amount of $\frac{9}{16}$ inch, while at *B* the 40-inch wheel drops but $\frac{3}{8}$ inch into the same hole. Evidently the larger wheel has an advantage in so far as passing over obstacles or holes is concerned.

Again, on account of its larger radius, the arc of the larger wheel is flatter and has more length of tread in contact with the surface of the ground, this being particularly noticeable on rough roads. Not alone does this mean added adhesion to the ground and thus lessening driving effort to propel the same car, but it also means a greater resistance to side slip or skidding, thus conserving the power and increasing the safety of the occupants. Other arguments could be offered in favor of large tires for easy riding, but those given should suffice.

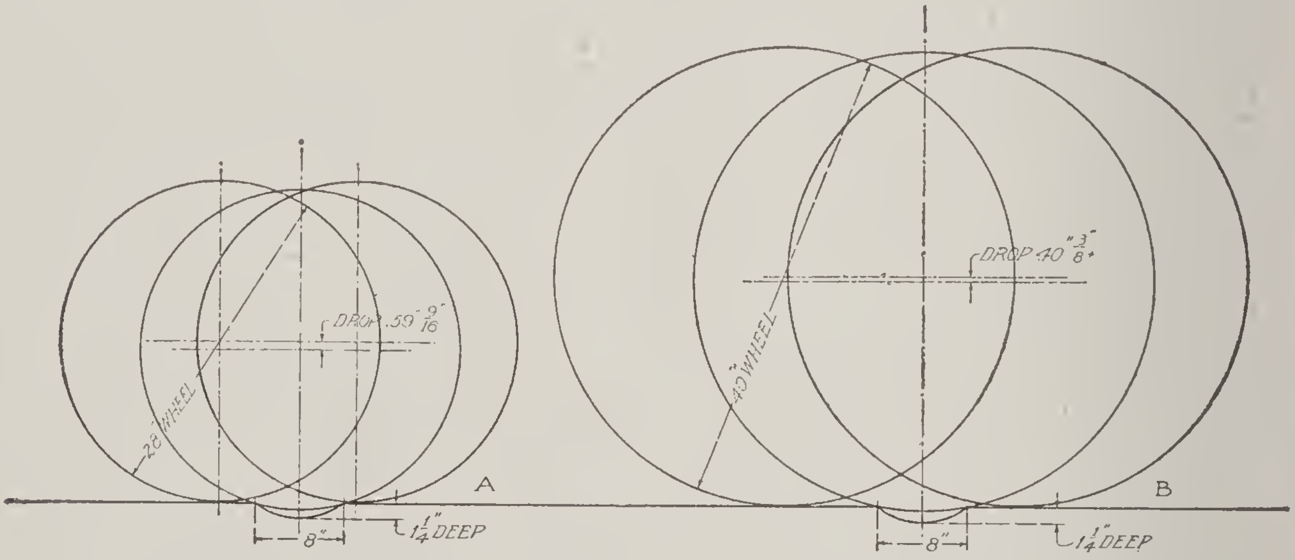


Fig. 488. Diagram Showing Advantage of Large Wheels in Passing over Depression

PLEASURE-CAR WHEELS

Wood Wheels. Wood wheels are the most common form for pleasure cars in this country, being almost universal. Ordinarily, they are constructed of an even number of spokes, which are tapered at the hub end and rounded up to a small circular end with a shoulder at the rim, or felloe, end. Fig. 489 shows this construction, *A* being the felloe on which is the rim *B*, and *R* is the spoke which, at the hub end, tapers down to the wedge-shaped portion *P*. This matches up to the wedge-shaped ends of the other spokes, so that when the wheel is assembled they form a continuous rim around the central or hub hole.

The spokes are held at their inner ends by metal plates and by through bolts, which are set at the joints between the spokes so as to pass equally through each spoke, as shown at *D*. Not only do these bolts hold the spokes firmly to the wheel, but they have an expanding, or wedging, action tending to make the center of the wheel very rigid.

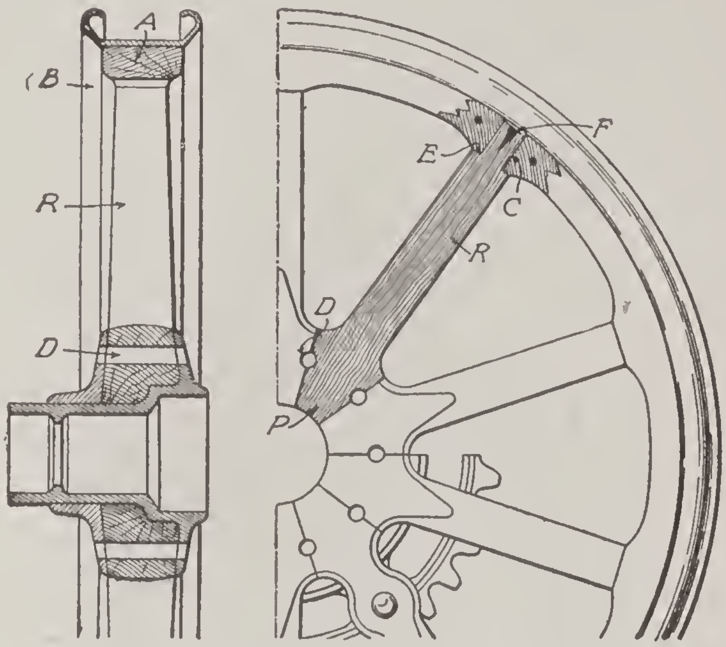


Fig. 489. Construction of Wood Wheels

The outer end of the spoke has a shoulder *E* and a round part *C*, which fits into a hole bored through the felloe. To prevent the felloe coming off after the spoke is in place, the spoke is expanded by means of a small wedge driven into it from the outside, as shown at *F*. In this way, the wheel is constructed from a series of components into a strong rigid unit.

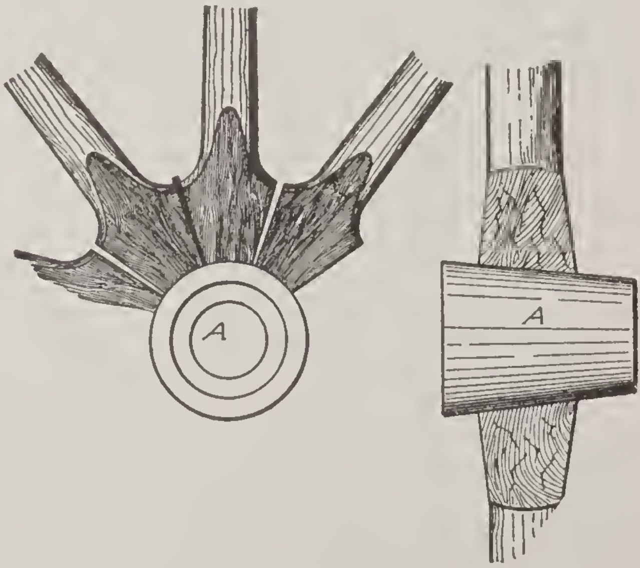


Fig. 490. Method of Tightening Spokes of Wood Wheels

Such wheels wear in two places, at the inner and at the outer ends of the spokes. The remedy in the latter case is to withdraw the small wedge and insert a larger one in its place. At the hub end, when wear occurs, this, too, must be taken up by means of wedges. Fig. 490 shows a method of doing this when the hub has no bolts at the joints. A false steel hub *A* is driven into the hub hole, after which wedges of steel are driven in between the wedge-shaped ends of the spokes. For slight cases of wear and squeaks, the wheel may be soaked in water, which will cause it to swell, taking up all of the space.

There are various modifications of this, nearly all of them changing the hub end of the spoke. In the Schwartz wheel, a patented form, each spoke is made with a tongue on one side of the wedge-shaped part and a groove on the other. In assembling the wheel, the tongue of each spoke fits into the groove of the spoke next to it, thus rendering the whole hub end of the wheel, when assembled, a stronger unit, being stronger in two directions, one of them of more than ordinary value. In driving the tongue into the groove, the wheel is rendered strong in a radial direction, but, when the wheel is entirely assembled, the tongue-and-groove method leaves it very strong to resist side shocks, a point in which the wood wheel is weakest.

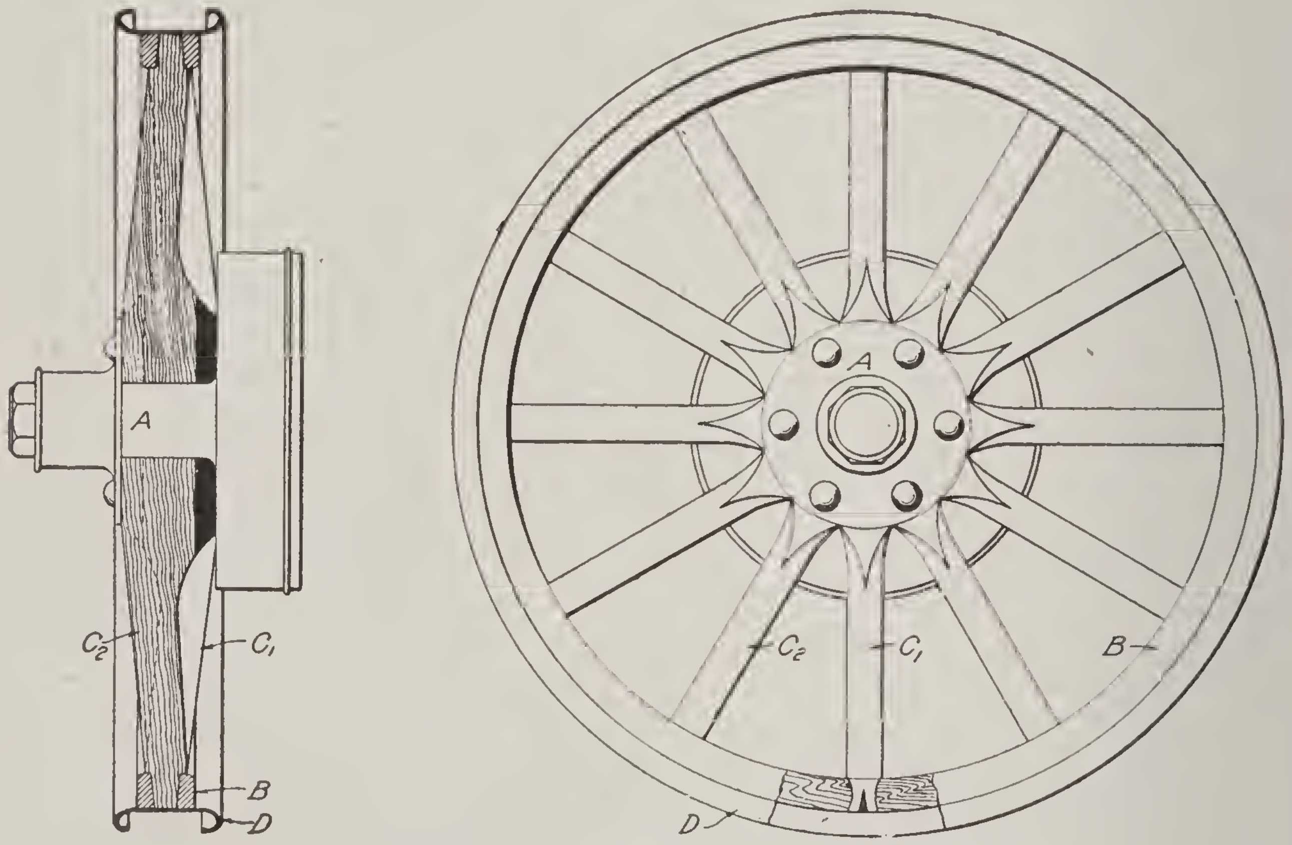


Fig. 491. Details of Wood Wheels with Staggard Spokes

Staggered Spokes. As mentioned above, the wood wheel has little lateral strength, nor can it ever have, from the very nature of its construction, except in unusual cases, like the Schwartz patent wheel just described. A method of increasing the lateral strength somewhat is that of using staggered spokes, these being alternately curved to the outside and to the inside, as shown in Fig. 491. This gives one set of half the spokes forming a very flat cone with its apex, or point, at the inner side of the hub, while the others form another cone with its apex at the outside of the hub. Each one of these conical shapes is stronger to resist stresses from the side on which the point is located than would be the same number of spokes set flat. Hence, the staggered-spoke wheel has the advantage over the ordinary type in that it has greater strength from both sides. In the figure, *A* is the iron hub, *B* the felloe, C_1 the right-hand and C_2 the left-hand spoke, and *D* the steel rim for the tire. This is a 12-spoke wheel, 6 of the right-hand spokes C_1 and 6 of the left-hand spokes C_2. The section shows how these pass alternately to the one side or to the other, forming the strong cone shape.

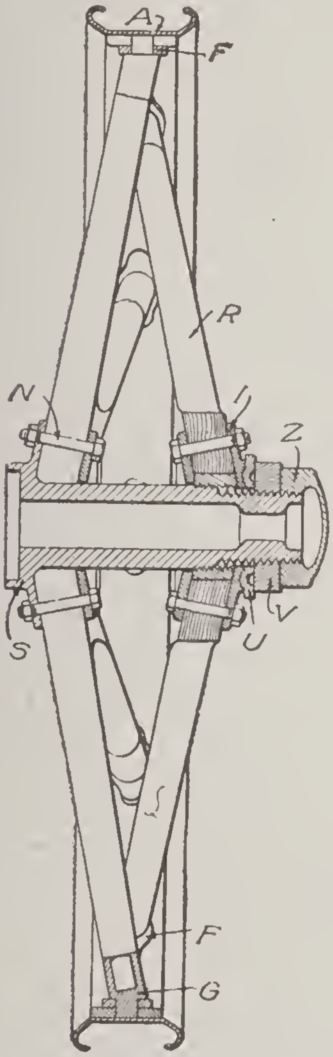


Fig. 492. Section of Steel and Wood Wheel

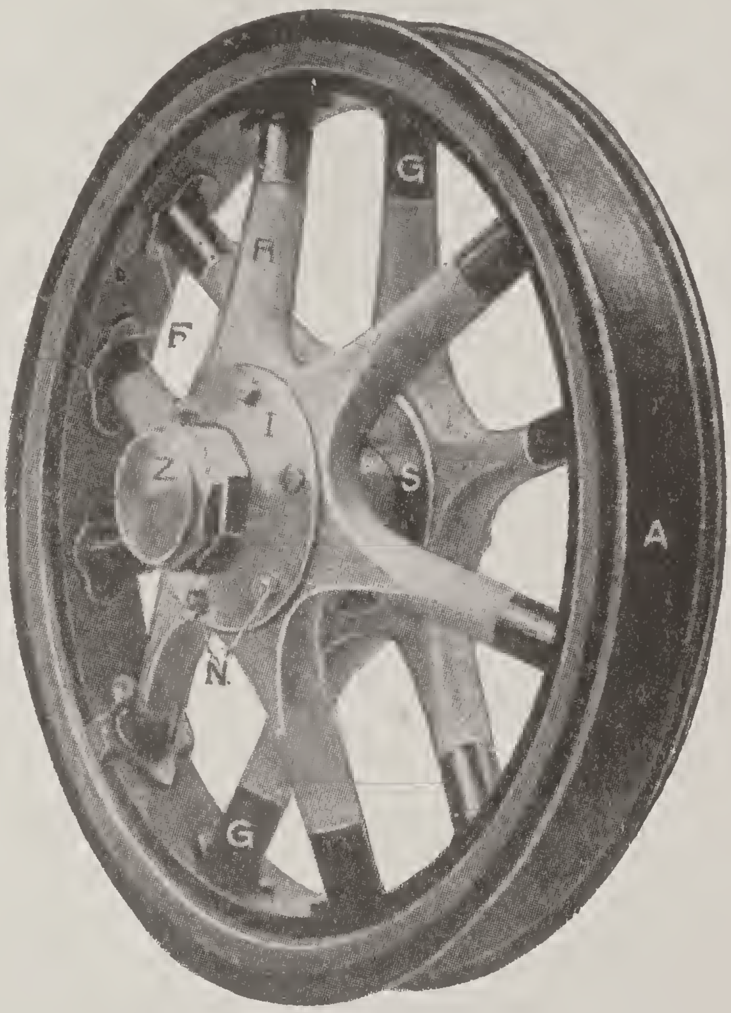


Fig. 493. Complete Steel and Wood Truck Wheel

Another method of handling this problem in a somewhat similar manner is the use of double sets of spokes, the spokes, however, being in two different planes separated a considerable distance at the hub. Of a necessity using the same felloe, the outer ends must be in the same plane. Fig. 492 shows a drawing representing a section through the center line of the wheel, while Fig. 493 shows a photographic reproduction of it.

In Figs. 492 and 493, *A* represents the steel rim on the felloe *F*, the latter being of metal in this case, as is also the wheel so it may be disassembled. The spokes *R* have a tubular end piece of metal *G*, which is set over the rounded end of each spoke and fits into a hole in the felloe. *I* and *S* are, respectively, the inner and outer parts of the hub, which are held together and to the spokes by means of the bolts *N*. *Z* is the hub cap, while *U* and *V* are filler pieces aiding in the dismantling process. The strength of the wheel is self-evident, but it is difficult to see the advantage of the disassembling feature, as a stress or strain which would break one spoke, would, in almost every case, break practically all of the spokes, thus necessitating a new wheel instead of new spokes.

Wire Wheels. Many of the little details of the automobile were inherited from its predecessor, the bicycle. Among these may be mentioned the wire wheel. Practically all bicycle wheels were and are of the wire-spoked type, and this same form of wheel was used on all earlier automobiles. It had no strength in a sidewise direction, nor did it, in fact, have much of anything to recommend it except its light weight. For this reason, it failed in automobile service, and received a setback from which it has even now not wholly recovered.

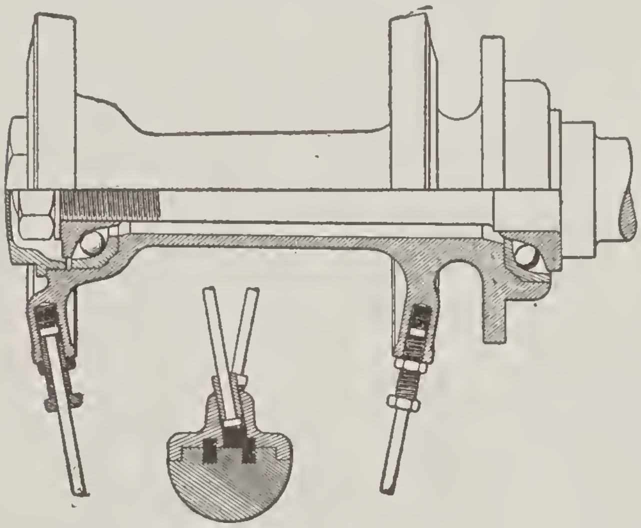


Fig. 494. Hub Details of Bicycle Wheel

Early Bicycle Models. Fig. 494 shows an early type of wire wheel for automobiles, its construction indicating clearly its bicycle ancestry. The spokes were set into a casting, which formed the hub, and into the steel rim by means of a threaded sleeve, the head on each end of the spoke resting on the inner end of the sleeve. The sleeves were screwed in and out to adjust the tension of the spokes. This tension was usually considerable, thus reducing in part the ability of the wheel as a whole to resist side stresses, for the piece already in tension could not be expected to sustain additional tension, or compression, or a combination of either with torsion, according to the way the force was applied. Then, too, the casting for the hub was wholly unsuited to resist stresses, and the distance apart of the spokes at the hub was not sufficient, making the cone so very flat that it had very little more strength than a perfectly flat wheel.

Following the failure of wire wheels, there was a rapid change to wood wheels, which were almost universal for several years. Soon after this change was made, there was an increase in the size and power of automobiles, which, in turn, was followed by a demand for lessened weights. In the meantime, makers of wire wheels, knowing their faults, began to re-design in order to eliminate them. Their success is best evidenced abroad, where about one-half of the French and more than two-thirds of the English cars, in addition to over seven-eighths of the racing cars in both countries, are now equipped with wire wheels.

New Successful Designs. This result has been brought about by a realization of the previous defects and their elimination. Thus, no more cast hubs are used, drawn or pressed steel of the highest quality and greatest strength being used instead. The spokes have been carried out farther apart at the hub, obtaining a higher cone and thus a stronger one. Spoke materials are better and stronger, besides being used in greater quantities, that is, larger spokes and larger numbers of spokes per wheel, in some cases a triple row of spokes being used in addition to the ordinary two rows. This additional row acts as a strengthener and stiffener much like the diagonal stays on a bridge. Fig. 495 shows a set of double-spoke wire, triple-spoke wire, and interchangeable wood wheels side by side for comparison, while in Fig. 496 is presented a recent triple-spoke front wheel in detail.

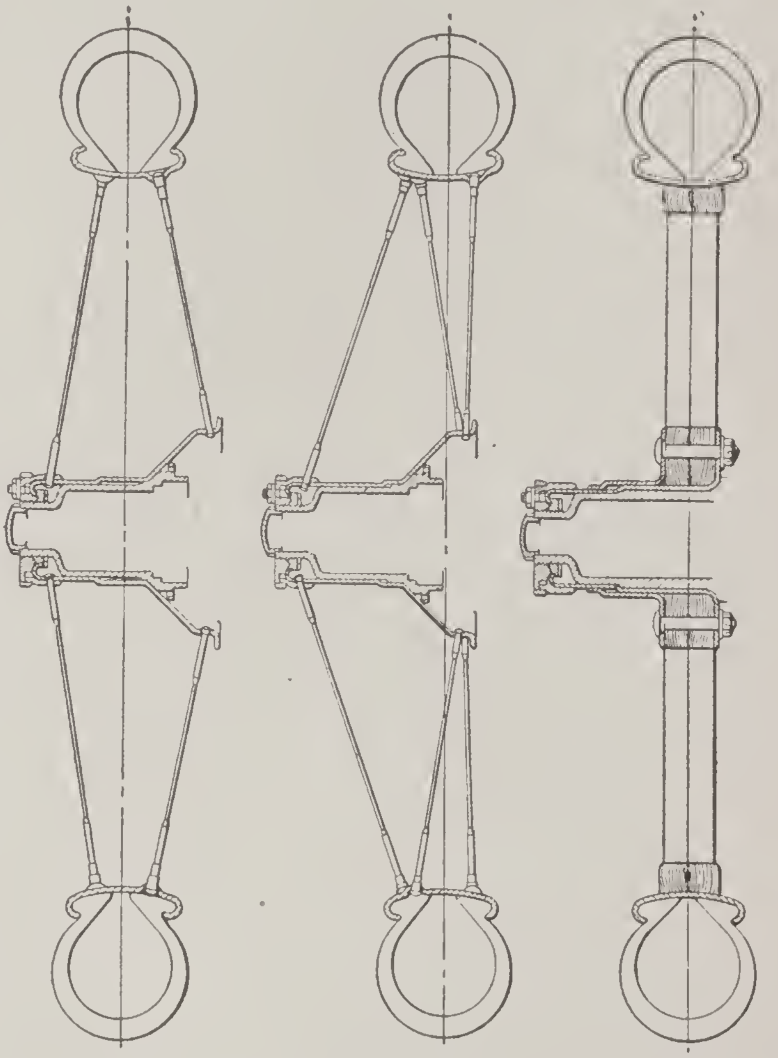


Fig. 495. Sections of Double and Triple Steel and Wood Spoke Wheels

In the former figure, the relative depths of the various cones and their corresponding strengths are made evident, being side by side. In this comparison, it will be noted that the new triple-spoke wheel has a much longer outer cone than the double-spoke wheel, while, on the other hand, the inner cone has been flattened. The triple spoke has a greater depth, considering the set of them as an additional cone, than has the inner cone in the double-set wheels.

In examining closely the older double-spoke form and the newer triple type, it will be noted, also, how the wheel itself, or rather the tire and rim, have been brought closer in to the point of attachment, thus rendering the whole construction stronger and safer. In Fig. 495, it will be seen that the center line of both tire and rim passes midway between the inner and outer ends of the hub on double-spoke wheels, while on the triple form it is even with the inside end of the inner hub, being, in fact, farther in than is the case with the wood wheel. One thing will be noted in all these spokes, regardless of number, position, or inclination, and that is that their ends present a straight head. On the older bicycle spokes, the diagonal-spoke head was a great source of weakness, tending to create failure at the outset. The modern wire wheel is so constructed as to do away with this fault. By actual tests, the wire spoke—not the stronger triple spoke but the double spoke—has been found to have the following advantages: lighter weight for the same carrying capacity; greater carrying capacity for equal weight; superior strength from above or below in the plane of the wheel; lower first cost (it is doubtful if this will hold good for the newer triple-spoke forms); and, in addition, tests have proved superior strength in a direction at right angles to the plane of the wheel. So marked is the difference in weight of the two that five wire wheels are said to be lighter in weight than four wood wheels of equal carrying capacity.

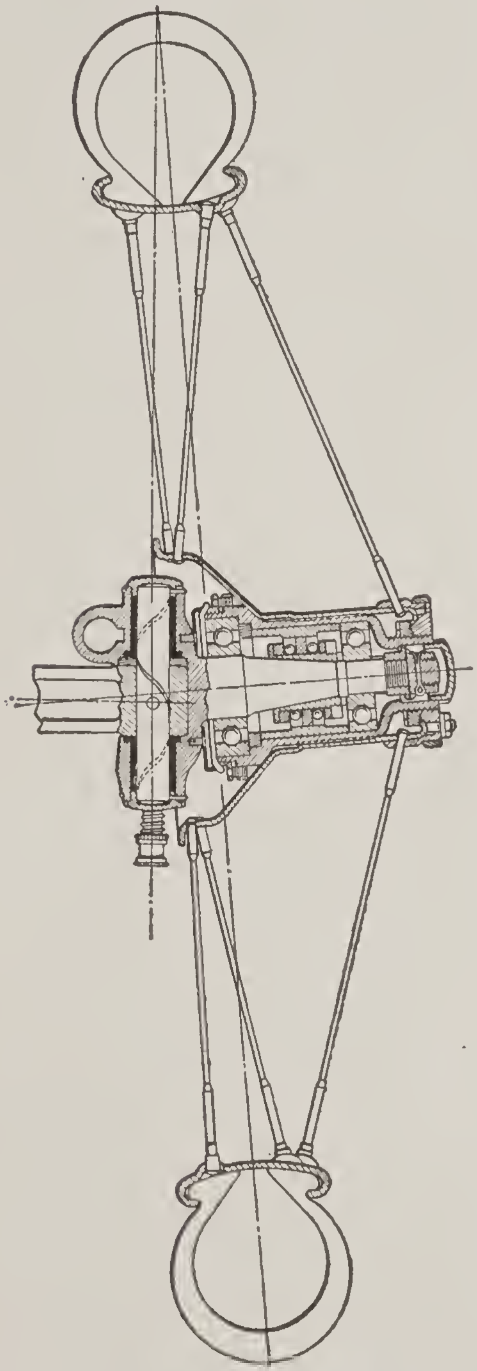


Fig. 496. Details of Triple-Spoke Front Wheel

All these arguments in favor of wire have been built up one by one, for much prejudice had to be removed. In spite of this, however, the wheel is slowly but surely building up a reputation and a long list of friends. Since, even now, England and the Continent continue to set the fashion in automobiles, it is not too much to expect to see wire-spoke wheels in common use in the United States in a few years. In fact, the dozen manufacturers offering this wheel in 1914, with ten more giving it as an option, have been increased to about forty who are fitting it regularly, with perhaps fifty or more offering it as an option in 1915. In fact, almost any car maker in the country will fit wire wheels for a slight additional charge.

For 1917 some 20 odd makes of cars are offered with wire wheels as regular equipment, and about 25 more offer this as an option without extra charge. As there are about 190 cars on the market, the former represents 10.5 per cent, and the latter 13.2 per cent of all makes; the two together total 23.7 per cent, or less than one-quarter. However, these figures do not quite indicate the relative popularity of wire wheels.

Wire Wheels Much Stronger. The increase in the use of wire wheels has been brought about by better designs; greater attention to the details of manufacture, assembly, and use; but primarily by the greater strength which has been built into the wire wheel. One way in which this has been done is by rearrangement of the spokes as, for instance, the triple-spoke form just described and shown in Fig. 469. Another and later form is the quadruple-spoke wheel as seen in Fig. 497. This is made and sold by the General Rim Company, Cleveland, Ohio, and is called the G-R-C wheel. As the sketch indicates, it has all the features of demount-

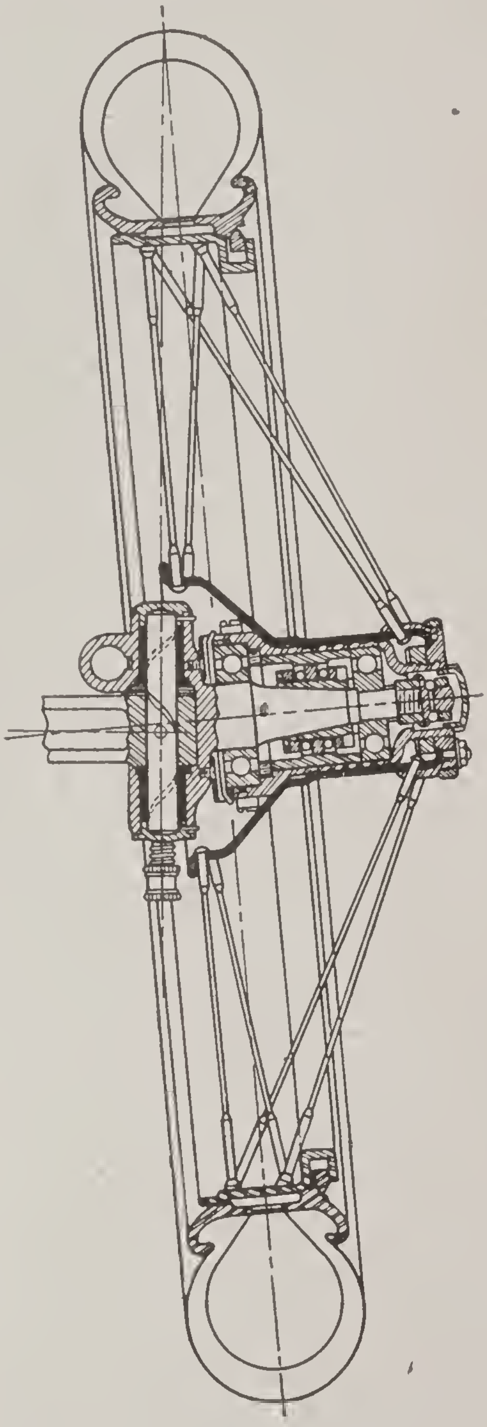


Fig. 497. G-R-C Quadruple-Spoke Wire Wheel

ability, etc., of other wire wheels, the notable differences being the spoke arrangement to give strength and the form of rim—a patented form to be described in detail later.

By comparison with Fig. 496, it will be noted that a double triangular section is formed in the G-R-C, the inner spokes forming the inside of the hub and the outside of the hub forming one triangle, while the outer spokes from each form the other. In Fig. 496, it will be noted that there is but the one triangle and a straight row of spokes.

Sheet=Steel Wheels. The sheet-steel wheel is really a form of wire-spoke wheel, with an infinite number of spokes joined together. It has many advantages, some of which might be mentioned as follows: strength, lightness, low first cost, low cost of maintenance, and cleanliness. To take them up in order, the strength of two steel plates set a few inches apart in a somewhat triangular form with the base toward the hub and well attached at the center and at the rim of the wheel, is self-evident. Aside from the natural strength of the steel plates—far in excess of the wire spokes—or round wood spokes, there is the strength of the triangular form. A strong connection at the top and at the bottom makes the whole construction very similar to a structural form. This shape closely resembles a box girder, having great resisting strength in all directions.

The light weight of the steel wheel comes from the thinness of the steel plates which are used, and similarly from the thin and light connecting members, either top or bottom. In Fig. 498 the junction at the top is seen to be nothing more than the steel rims for the tire, thus doing away with the usual felloe or substitute for it. In this figure, the wheel is seen to consist of the hub made with two flanges, to which the side sheets are bolted; the brake drum *I* bolted to the sheet on the inside, midway up its height; the steel rim mentioned before; and the bolts and rivets necessary to join the parts. At the hub, bolts are used to allow of dismounting the sheets in case of damage, for replacement or otherwise. At the rim, however, the plates are riveted to the rim, and riveted together.

Low first cost is brought about by the simplicity of the wheel. The wheel consists of the usual rim, not counted in the wheel cost, and two pressed-steel sheets flanged at the top, with a few holes punched in them. These sheets are very cheap to make, while the hub construction is much cheaper than the ordinary hub, for the reason that there are usually two parts where this construction requires but one, and this a very simple one needing little machining. Low maintenance cost is brought about by the rigidity of the whole construction; the few parts, which make few to replace or even to wear; the cheapness of these parts, when replacement is necessary; and the well-known strength and long life of sheet-steel plates.

On the score of cleanliness, it may be said that this is one of the drawbacks of the wire-spoke wheel, cleaning between and around the spokes being very difficult, if not actually impossible. The large number of spokes makes the hub inside of the spokes impossible to clean, whereas, with the sheet-steel wheel, the cleaning consists in merely turning a hose on the sides of the wheel, the cleaning of the hub being entirely unnecessary.

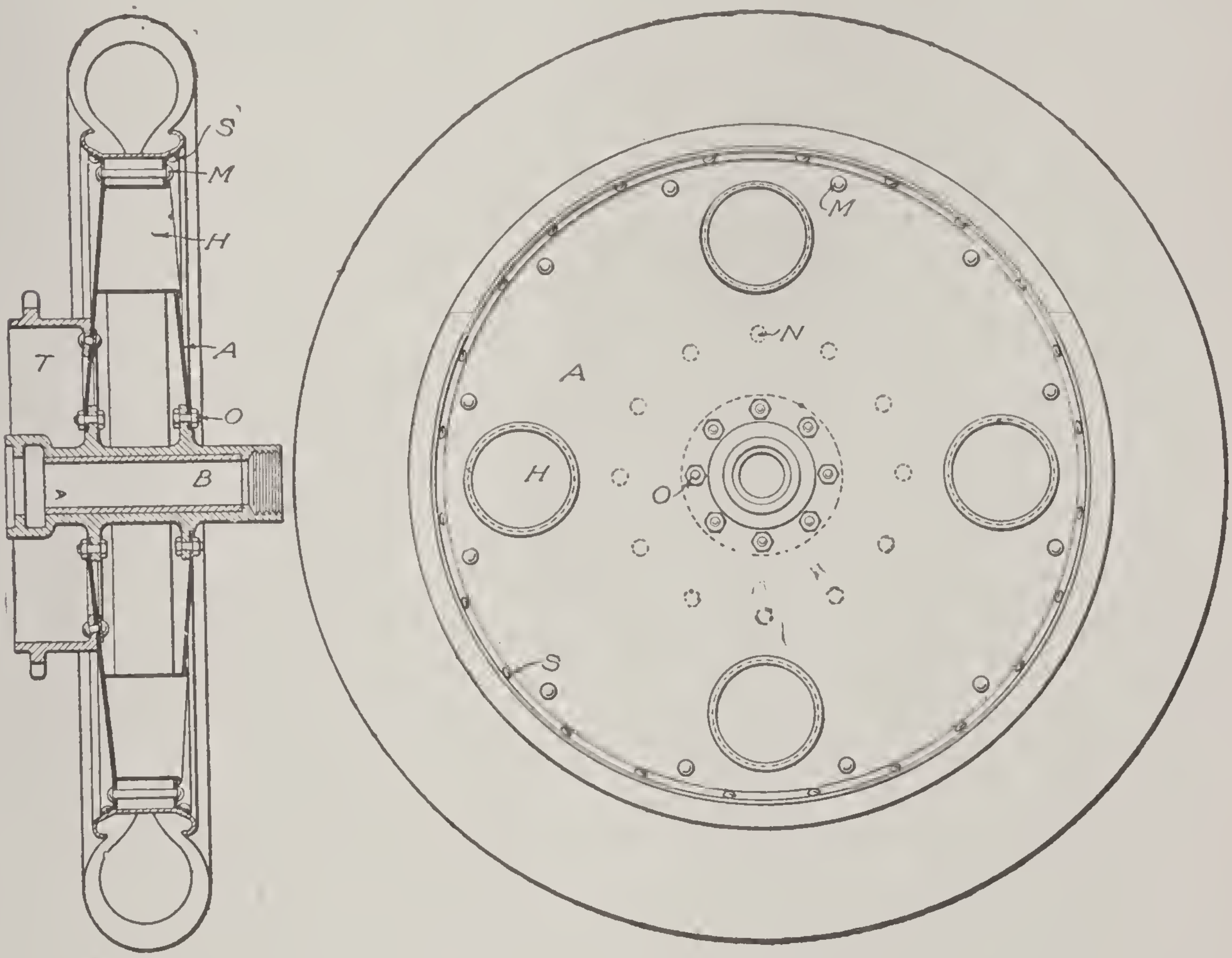


Fig. 498. Side and Sectional Views of Sheet-Steel Wheels

It will be noted, too, in this illustration that the wheel has considerable spring, or should have, in a vertical direction. It is claimed for this type of wheel that this springiness is an added advantage as it allows the use of solid or cushion tires, and thus eliminates the troublesome pneumatic tire with its puncture and blowout possibilities. For commercial-car use, all of the advantages just mentioned are of double worth, for which reason the steel wheel is making great strides forward on commercial cars. Where the springiness of the wheels is not so desirable as strength, the sheet-steel plates may be replaced with either pressed- or cast-steel side members on which strengthening ribs are formed. The sides of the wheel have holes *HH* through them which are provided for ventilation, to decrease the weight of the side sheets, and to lessen the wind resistance to the wheel when moving rapidly. In some steel wheels these holes are omitted; in others a larger number than the four shown here are used. Fig. 499 gives a better idea of the general appearance of the wheel ready to use, being lettered the same as Fig. 498. The spokes shown in Fig. 499 are painted on the smooth exterior of the plates, but in other wheels these spokes are formed in the plates as previously mentioned.

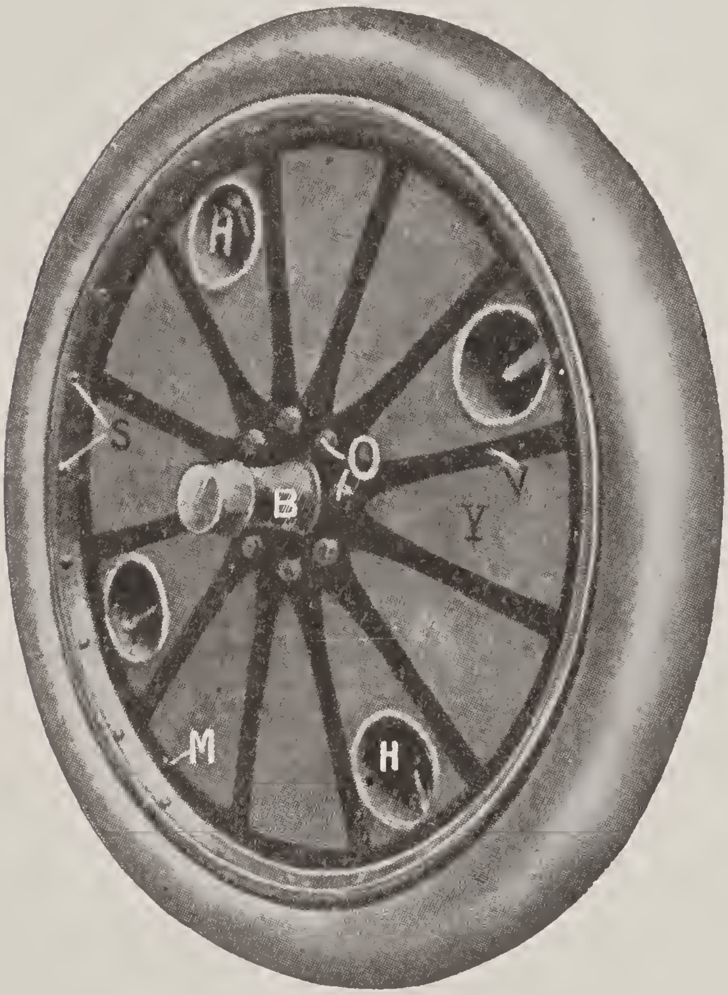


Fig. 499. Sheet-Steel Wheel Complete

Steel Wheels Designed for Cushion Tires. Sheet-steel wheels, particularly those of very thin sheets, have a certain amount of springiness, this being utilized with solid and cushion tires on the assumption that the wheel will absorb the vibrations set up by the road inequalities. In Figs. 500 and 501, a wheel is shown which was designed for this express purpose. The wheel is called an elastic wheel and uses solid tires.

By means of the figures the construction is made clear, the wheel consisting of two halves, one a single sheet of metal attached to the hub and forming its own rim portion, and the other a section which consists of two sheets, one attached to the hub and forming its own rim portion, with another additional plate riveted to it near its outer end and attached to a middle flange on the hub. The two outer members of themselves would be very springy and consequently very weak, being of very thin metal. The diagonal extra sheet stiffens the whole construction, besides adding 50 per cent to its side strength. This is also of thin metal, so the whole wheel retains some springiness.

Parker Pressed=Steel Wheels. One fault with all the steel and sheet-steel wheels mentioned was that they did not resemble other wheels, consequently the people did not want them. Moreover, in many cases, their construction did not adapt them to the use of regular tires but, on the contrary, called for special and expensive forms. However, none of these drawbacks are present in a new form of pressed-steel wheel, Fig. 502. Upon close inspection it will be seen that this wheel has no felloe in the ordinary sense, the rim of the wheel forming the only felloe. In this respect, the wheel is an outgrowth of the former Healy demountable rim, the modern form being a combination of a demountable rim with steel spokes. This wheel is suitable for any car, the hollow steel spokes having great sustaining power. It is interchangeable with all ordinary wood artillery wheels of the same size, and fits between the usual hub flanges. The spoke portion is made as a pair of units, each forming half of all the spokes, the two being welded together. When finished in this manner, they have half the weight and more than twice the strength of the wood wheel, the greatest saving being at the rim, by the removal of from 60 to 100 pounds of metal and wood.

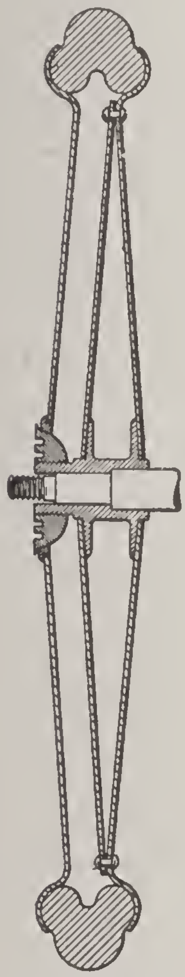


Fig. 500. Steel Wheel

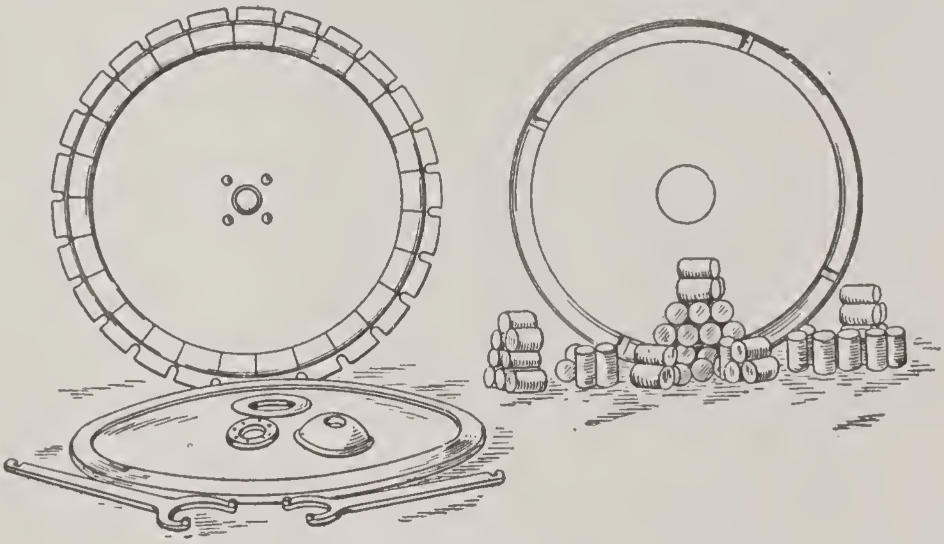


Fig. 501. Disassembled Steel Wheel

This wheel takes the ordinary demountable rim directly upon the ends of the spokes, the one shown being the No. 2, which is suitable for about twelve different rims as made by the largest manufacturers. The No. 1, whose only difference in appearance is a flat spot just under the bolt heads at the ends of the spokes, takes all one-piece clincher or straight side rims, whether clincher or Q.D. (quick detachable). The wheel shown is a 36- by 4½-inch size, made from .083-inch sheet steel, with ten spokes 1¾ inches round and a center portion, all of the same thickness of steel.

A number of other pressed-steel wheels, made, like the Parker, by pressing out two or more simple units, and welding these together, are making their appearance. These show great ingenuity and variety in the methods used to produce this same result and yet avoid the Parker patents. This form of wheel, having the appearance of wood, yet with greater strength and dependability and also of lighter weight, may perhaps be the final answer to the wheel problem; certainly this is possible if quantity production can bring them down below the price of wood wheels, which now seems apparent.

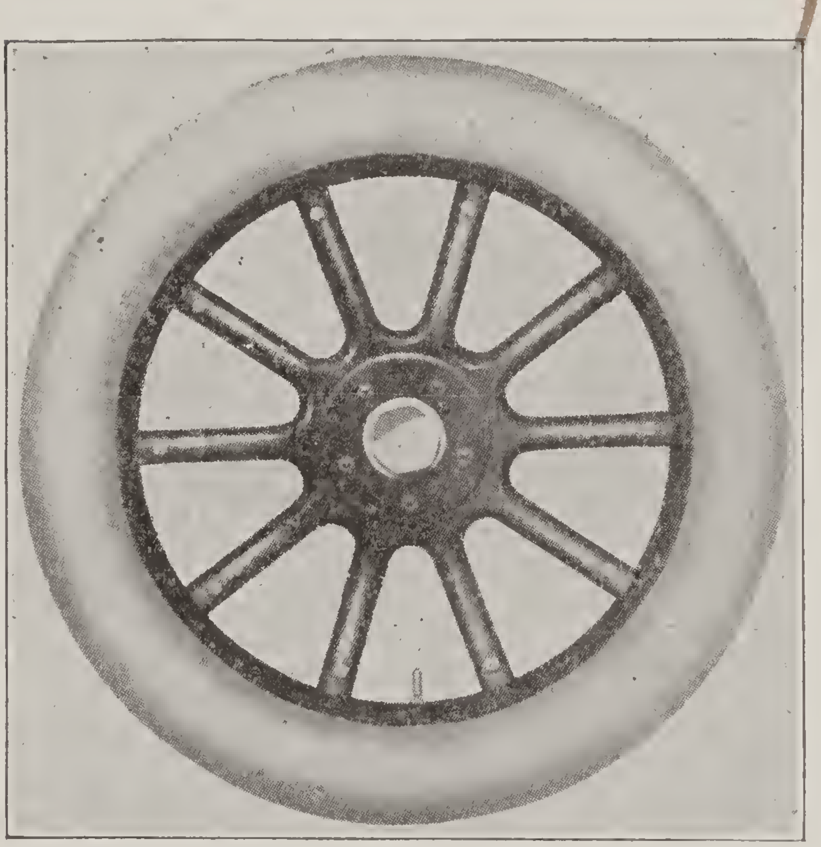


Fig. 502. General Appearance of Parker Hydraulic Steel Wheel

COMMERCIAL-CAR WHEELS

Requisites. On commercial cars the service is so different as to call for entirely different wheels. Of course, many commercial-car wheels are nothing but pleasure-car wheels with heavier parts throughout, but it is coming to be recognized that heavy trucks, tractors, and similar vehicles should have their wheels designed for the service required of them the same as lighter cars. No springiness or resiliency is required for heavy truck service, but simply these three things: strength to carry load and overloads; strength to resist side stresses; and such material, design, and construction as will make for low first cost and low cost of maintenance. A fourth desirable quality might be added to these, the quality of being adaptable or adapted to the tires to be used.

Wood Wheels. Taking Fig. 503 as an ordinary heavy vehicle wheel, let us see in what ways it fulfills or falls short of these requirements. The spokes are large in both directions and widened out at the felloe to give greater side strength. The felloe, which cannot be seen, may be judged as to size from the width and location of the dual tires, which would indicate great width and considerable thickness. This style of tire calls for a steel band shrunk over the felloe, while the heads of the cross-bolts show how the tires were put on and held on. All these make for great strength in both horizontal and vertical directions, and all parts except the spokes are simple to make, and even these are simple for the wheel manufacturer whose shop is rigged to make them. Moreover, to fill the last requirement, the wheel is adaptable to this tire or to any one of a number of motor-truck tires which might be used.

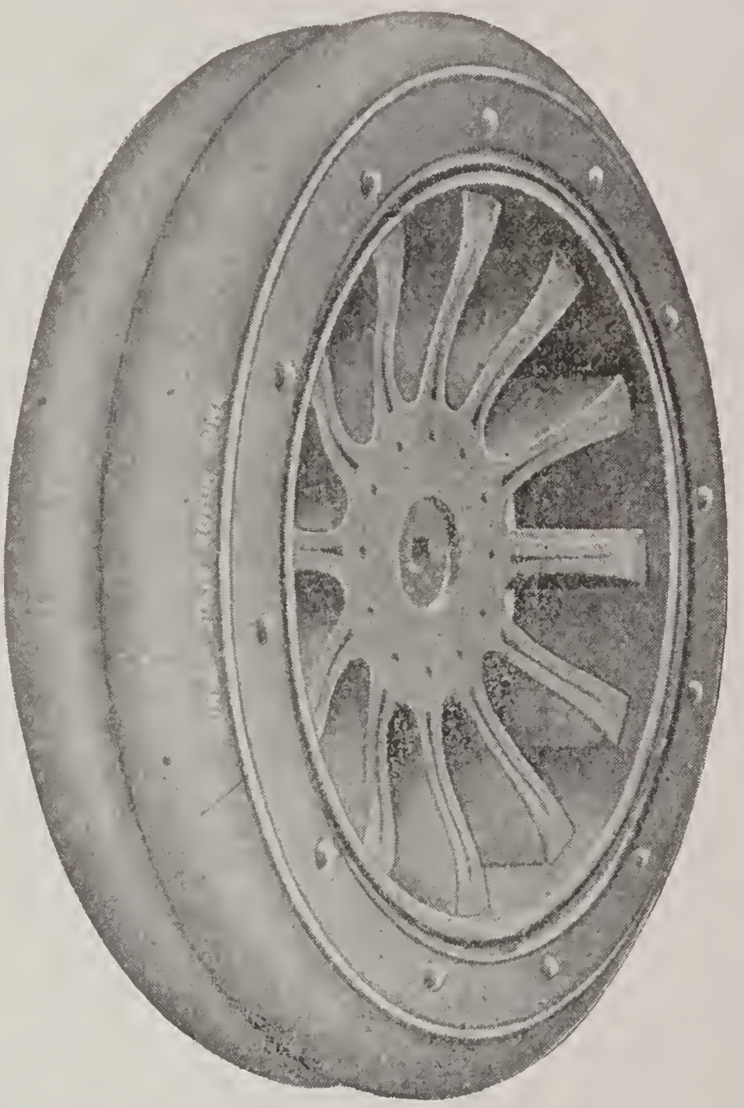


Fig. 503. Double-Tire Wood Truck Wheel

A slight variation from this is the double-spoke wheel, in which the spokes, in addition to being placed in double rows, are set so as to miss each other across the wheel, that is, each spoke of one row coming between two of the other. This placing allows the spokes to be made larger and stronger than in the ordinary case, while the double rows have the same strengthening effect as the tapering of spokes. The hub portion is assembled as two separate wheels, so that the work of assembling as well as of making the parts is slightly more than with the ordinary wheel. This is more than compensated for by the added strength. It is but fair to state that each of the last two wheels described is of English make.

In all wood wheels, the blocks composing the wheel and tire are of well-seasoned rock elm, sawed into wedge-shaped blocks, with the fiber lengthwise. The blocks are glued and nailed together until they form a circle. They are then turned round and to size in a large wood lathe, a shoulder $\frac{1}{2}$ inch wide being formed at the same time on each side of the tire 2.5 inches from the tire surface. A heavy steel ring with a corresponding shoulder is then shrunk over the wood shoulder on each side of the tire, drawing it together much like the ordinary steel tire on a wood wheel of a carriage. Bolts are run through these rings and through the wood blocks from side to side to prevent the blocks from splitting sidewise. To increase the life of this tire, steel wedges $\frac{1}{4}$ inch thick are driven crosswise into the face of it 2.5 inches deep around the whole tire about 3 inches apart. These wedges prevent the tire from slipping; in fact, they act like an anti-skid chain and do not harm the pavement, being set flush with the surface of the wood blocks.

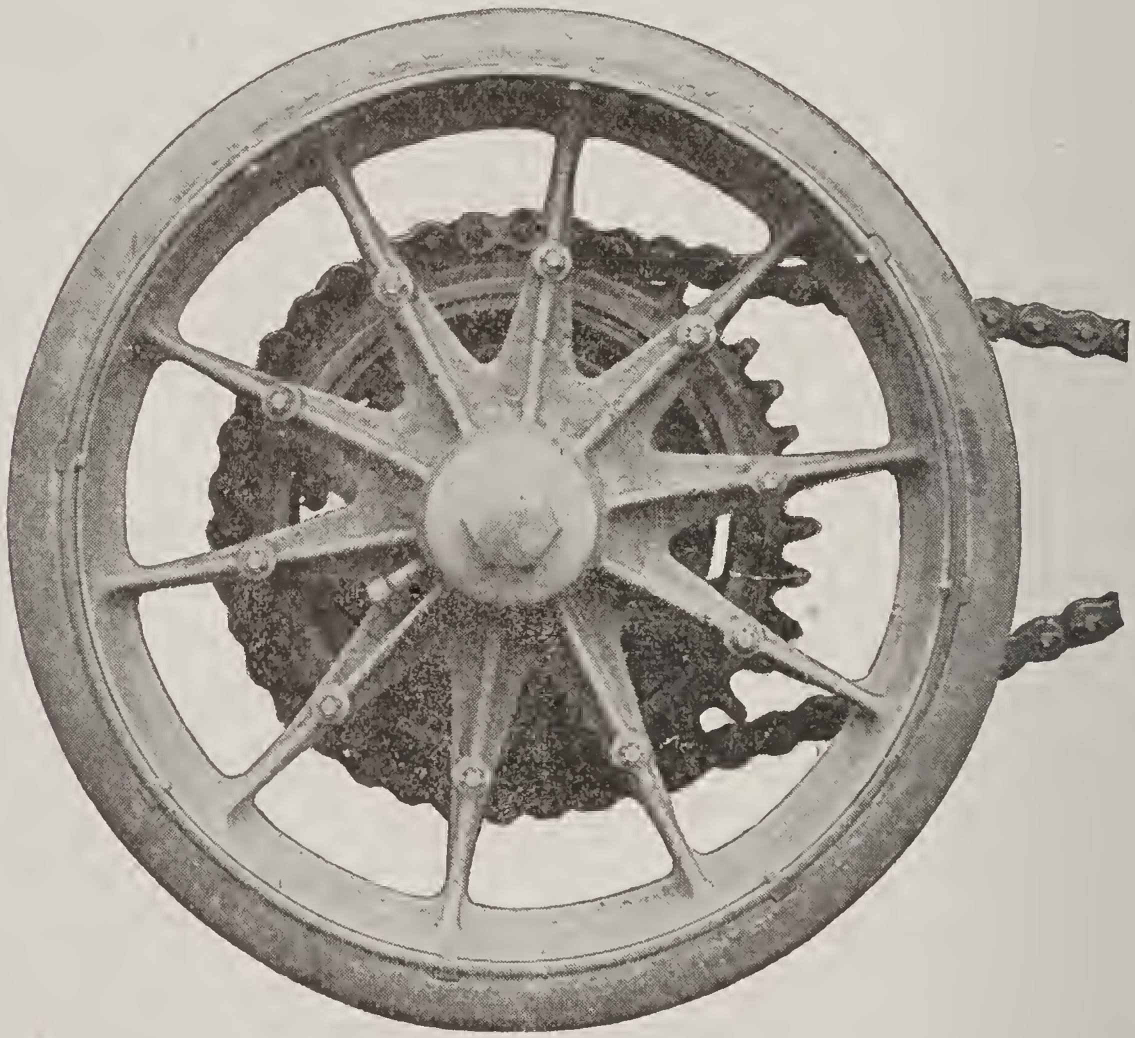


Fig. 504. White Cast-Steel Wheel

It is said that one set of these tires was used for nine months, and at the end of that time they were still good for service. The tires reach clear to the hub, thus doing away with spokes and enabling the tires to be slipped over the hub and held in place by a removable flange bolted through the wood to the fixed flange on the opposite side of the hub.

Cast-Steel Wheels. The heavier the service the more unsuitable do wood wheels become, that is, wood-spoke wheels. For many five-ton trucks, practically all seven- and ten-ton trucks, and nearly all tractors, the cast-steel wheel is used, either spoked or solid, the spoked form being given the preference. Fig. 504 illustrates a spoked cast-steel wheel, fitted with a solid tire. The wheel is cast with ten heavy ribbed spokes, a ribbed felloe, and a grooved-felloe surface, into which the tire is set.

Miscellaneous Wheel Types. *Steel.* Steel wheels are gaining for heavy truck use, and a number of the better steel-casting firms are now getting into this work, with the result that better steel wheels are becoming available.

Other constructions, such as steel and wood combination wheels with removable and replaceable spokes, and the like, are rapidly going out of existence. Truck work is unusually severe, and it takes but a few weeks of actual use to show up any of the so-called freak wheels. The simplest seems to be the best, the only question at present being whether the material shall be wood or cast steel. Pressed steel may offer some opportunities in combination with welding, since good work has been done on pleasure-car wheels of this type.

Spring Wheels with Longitudinal and Tangential Springs. Spring wheels for both pleasure cars and trucks have not proved to be all that was claimed for them. For pleasure-car use they have gone out entirely; for truck use they are restricted to the smaller and lighter sizes, as the 1½- and 2-ton sizes driven at high speeds in city work. On these sizes, one or two well-designed forms are giving good service. The cherished dream of putting the pneumatic tire out of business through the medium of the spring wheel is still a dream.

When longitudinal springs are used to do away with the alternations of stresses peculiar to the radially disposed springs, the appearance of the wheel is much altered, as Fig. 505 shows. This wheel consists of an inner wheel, having its own spokes—ten in number—and its own felloe. To the felloe are attached by means of bolts V-shaped arms, which hold one end of a series of spiral springs, the other end of each of the springs being held in a similar V-shaped arm bolted to the opposite side of the outer felloe carrying the tire. There are eighteen of these springs in two sets of nine each. Those springs which have their near end fastened to the near side of the inner felloe have the far end fastened to the far side of the outer felloe, while those attached to the far side of the inner felloe have the other point of attachment on the near side of the outer felloe.

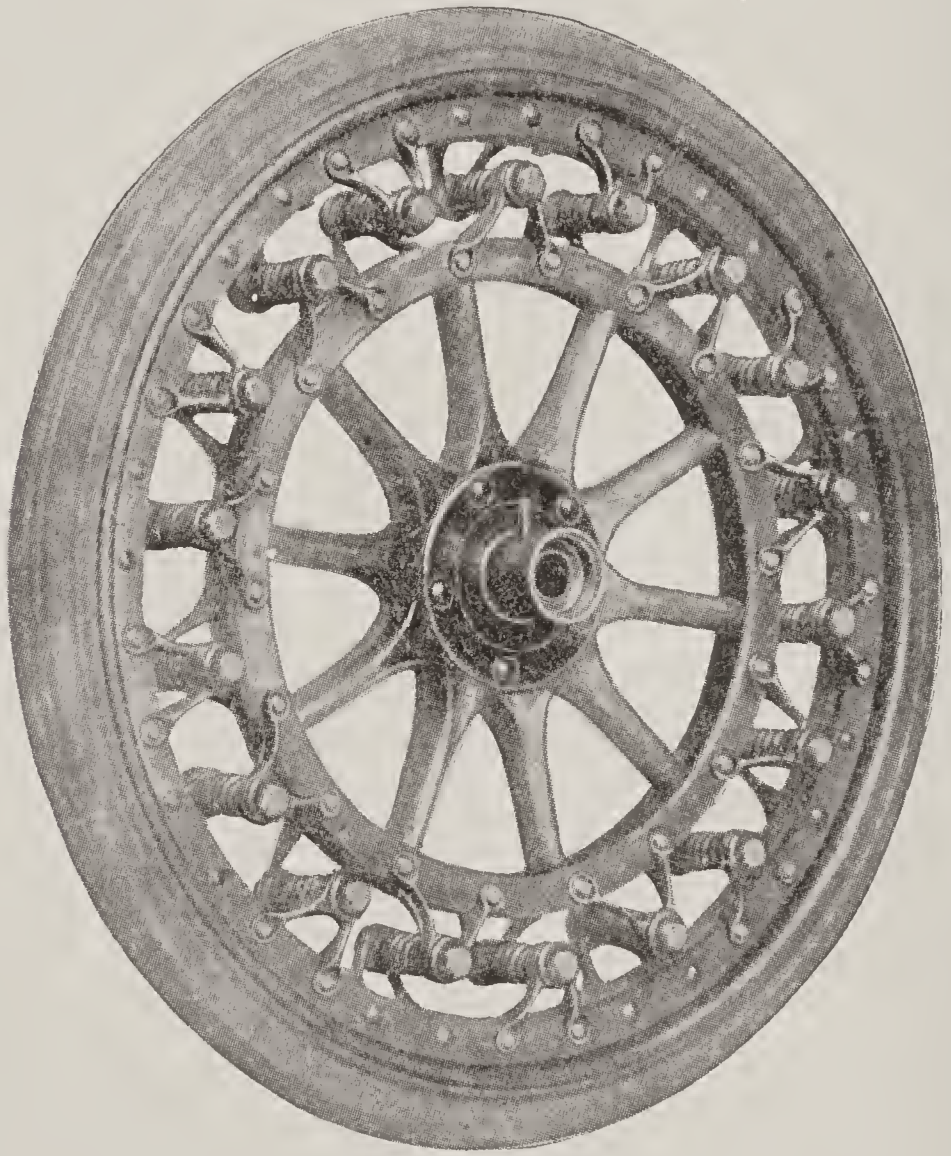


Fig. 505. Seaton (American) Spring Wheel

When the wheel strikes an obstacle, a twisting action is set up, the outer felloe and tire moving while the inner felloe and axle remain stationary. This twisting of the springs tends to coil them tighter, which results, when the obstacle is passed, in the springs untwisting and turning the outer felloe and tire backward as far as it was previously moved forward. Since, however, the springs have a certain amount of stiffness in their coils, and the wheels do not rise and fall relative to one another, except in so far as the twisting action is concerned, it follows that considerable shock must be transmitted to the axle and thus to the body and its occupants. This wheel, therefore, while possessing strength to resist side stresses, does not give the smooth riding qualities so much desired.

A wheel very similar in appearance and action but with the wood spokes eliminated has been used very extensively in the last few years by the express companies and other big users of motor trucks. Starting with a few of them on front wheels, they have saved tires and tire money to such an extent that the companies have added more and more. Next they were tried on rear wheels. Seeing the good results obtained by the big companies with these wheels, many smaller firms and tradesmen with only one or two trucks have adopted them. They take a small size solid tire in place of a very large pneumatic and are said to cut the tire cost from one-half up to two-thirds and more. While used mainly for vehicles carrying a 1-ton load, they have been tried successfully on 2-ton vehicles.

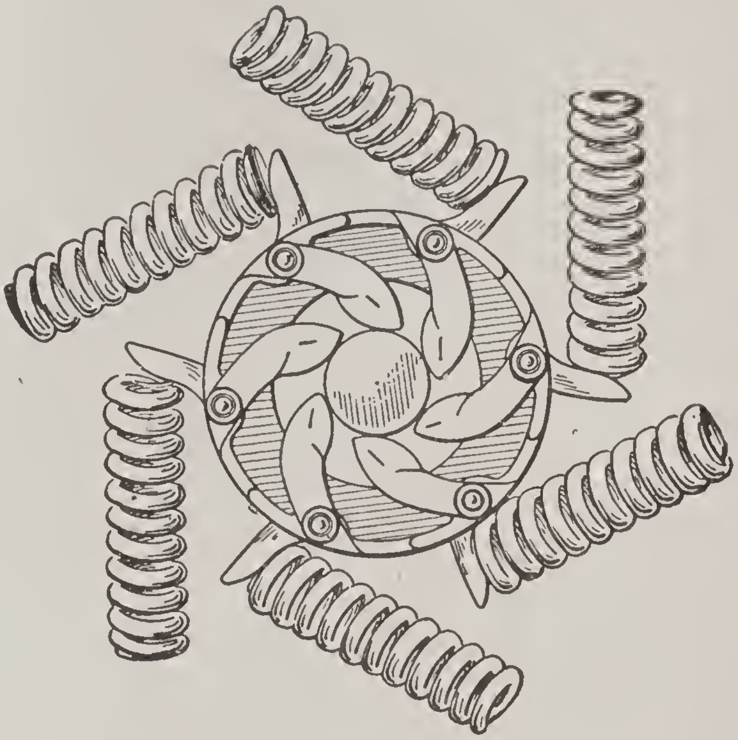


Fig. 506. Diagram of Action of Taylor Spring Wheel

It is in this class of service—the lighter vehicles for smaller firms—where every item of expense must be watched very carefully that the resilient wheel should show the best results. For heavy work, there seems little future for it.

A form of wheel which comes somewhere between the two just mentioned, having some side strength and easy-riding qualities, while at the same time participating in part of the principles of both those described, is that shown in Fig. 506, which is a diagram showing the construction. This consists of spiral springs used not radially nor longitudinally, but tangentially. Moreover, the springs are not attached directly to the hub, but to levers pivoted on an outer, or false, hub. When an obstruction is met with, so that the tension of the springs is altered, the springs act upon the levers and thus turn the false hub about the real inner hub by an amount corresponding to the character of the obstruction. This eccentric motion of the outer hub, induced by the spring action, takes up the shock of the road obstruction much as does the wheel shown in Fig. 505.

The construction is such as to allow of the springs being covered by means of a water-tight case, which will protect them from the elements and thus lengthen their life. This is a good feature which is lacking in all other wheels thus far shown.

Spring Wheels with Flat Spiral Springs. The flat spring bent into a semicircular or spiral form is little used for spring wheels. There is a double reason for this; they lack every desired quality, unless it be side strength. If stiff enough to handle considerable load, they are heavy, they are slow acting, and their action is long continued; if made light, they act too much and the vibrations are long drawn out. Moreover, if few springs are used, the breaking of a single one puts the wheel out of use; if many are used, the wheel becomes very heavy.

While a number of flat-steel spring wheels have been constructed both here and abroad, they have not been uniformly successful, as has been pointed out. A French form which was widely tried a few years ago had a pair of sets, each of six springs, with a long curving shape, one end attached to the hub and the other to the rim, while the leaves on the two sides were set in opposite directions. The idea was that loading would produce an eccentric movement of the rim relative to the hub, and that the opposing of the two sets of leaves would produce an absorption, one side absorbing the tendency to movement of the other. In practice, however, this idea did not work out, as it gave a noisy, hard-riding wheel, with a tendency for the springs to break. These disadvantages, added to its weight, put a stop to its use.

An American device, constructed along somewhat similar lines, but with all springs pointed in one direction, had only a limited use in the home town of the inventor and is not now used.

Modern Status of Spring Wheel. The more modern view is not that the solid tire will be eliminated, but that a form of steel-spring or other resilient wheel will be produced which will have all the advantages of wood and, in addition, will so save the solid rubber tires that mileages twice as great will be obtained. In this way, the tire cost will be cut in half, which will be sufficient within the ten-year life of the ordinary commercial car to warrant the purchase of the more expensive wheels.

In the use of spring wheels, as well as of wire wheels for pleasure cars, the tire and rim situations are closely inter-woven. No special form of wheel or rim can be successful which calls for a special tire in addition, because, in case of trouble on the road, in a small town, or anywhere outside of the big cities with large and varied sources of supply, the users would not be able to replace the tire. As will be pointed out later, the present rim-and-felloe situation, which might be described as chaotic, must necessarily continue until the tire situation is cleared up. That done—and it is now in a fair way of being done soon—the rim situation also will be quickly cleared up, and, following, that of the wheel felloes. The natural fitness of the various forms and the unfitness of others to meet popular demand is rapidly clearing the way for the engineers and manufacturers who are attempting this standardization work.

WHEEL TROUBLES AND REPAIRS

The removal and handling of wheels present probably the biggest problems in connection with them. True, broken wheels give the repair man a good deal to think about, but the quick accurate handling of jobs in which a broken wheel figures depends more upon possessing and knowing how to use certain equipment than anything else; the operations are so simple that they require no particular skill or knowledge.

Wheel Pullers. In handling wheels a wheel puller of some form is generally a necessity; wheels are removed so seldom that they are likely to stick, and they get so much water and road dirt that there is good reason for expecting them to stick or to be rusted on. This means the application of force to remove the wheel. For this purpose, a wheel puller is needed, and a number of these have been illustrated and described previously, as gear pullers, steering-wheel pullers, etc. Any one of these devices which is large enough to grasp the spokes of the wheel and pull the latter outward and, at the same time, press firmly against the protruding axle shaft will do the work well.

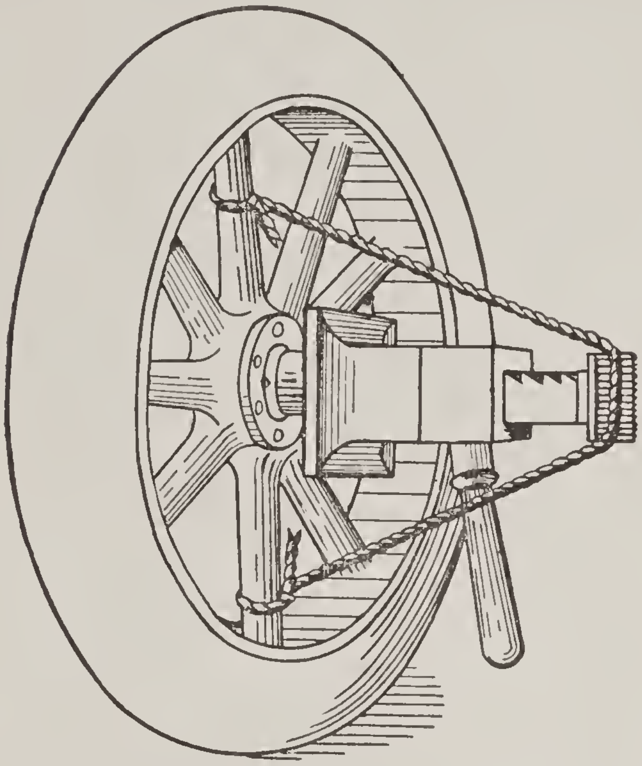


Fig. 507. Makeshift Wheel Puller for Road Repair Work

Sometimes, however, while owning a puller, a wheel breaks down on the road where this is not available, or the repair man is called without being told the trouble, so that he does not bring the puller with him. In such cases, the repair man must improvise some kind of a puller out of what he has on hand. Everyone carries a jack, so it is safe to assume that one of these will be available as well as some form of chain. If a chain of large size is not available, tire chains—particularly extra cross-links—may be fastened together to answer the purpose. If chain is lacking, strong wire, wire cable, or, in a pinch, stout rope can be substituted. Attach the rope, wire, or chain to a pair of opposite spokes of the wheel, Fig. 507, allowing usually about two feet of slack. Draw the chain out as tightly as possible, place the jack with its base against the end of the axle and work the head out by means of the lever until it comes against the chain. Then by continued but careful working of the jack, the wheel is pulled off the axle.

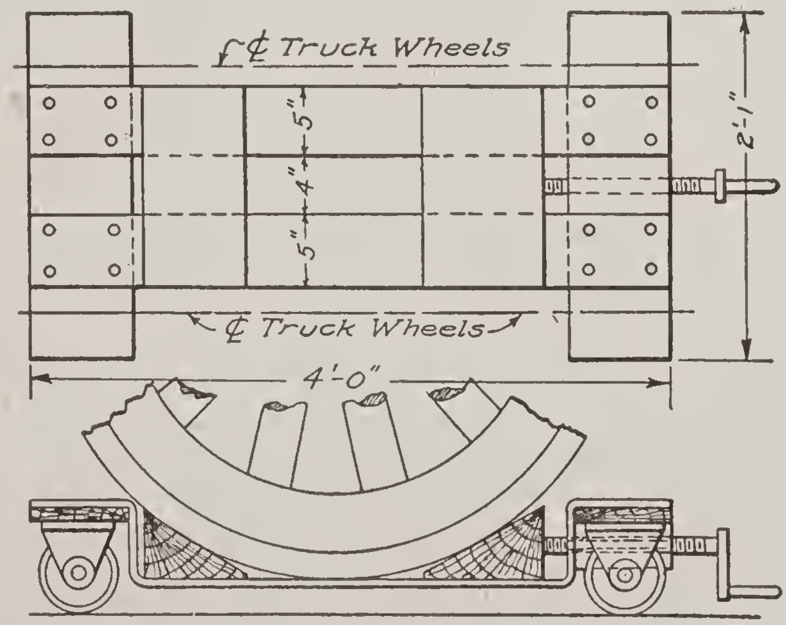


Fig. 508. Tire Platform or "Dolly" for Handling Truck Wheels

If rope, wire, or wire cable is used, it is advisable to place a heavy piece of cloth, burlap, or something similar over the head of the jack to prevent its edges cutting through this material. With rope only enough slack must be used to allow the jack in its lowest position to be forced under it; this must be done because there is so much stretch to the rope itself and so little movement in the ordinary jack, that the combination of rope and jack does not always work to advantage.

Similarly, the handling of heavy truck wheels gives much trouble even in the garage, for they are so big, heavy, and bulky that ordinarily two men are needed. One man can do the trick, however, with a platform or "dolly" like that shown in Fig. 508. This consists of a platform about 4 feet long by 25 inches wide, fitted with casters at the four corners. Inside of the central part are placed a pair of wedges, one of which can be moved in or out by means of a crank handle. To use this, the wheel is jacked up a little over 2 inches, and the truck pushed under. Then the movable wedge is forced in against the tire so that the two wedges hold the wheel firmly and carry all of its weight. Then the casters are turned at right angles so that the platform and the wheel may be moved off together. The truck wheel is removed in the usual manner, that is, with the aid of the wheel puller or such other means as the garage equipment affords. The dolly also forms a convenient means of handling the wheel when it is put back on its axle.

TIRES

Kinds of Tires. Broadly, there are three general classes of tires: the solid, the pneumatic, and the combination or cushion. The solid tire needs little comment or discussion here—being solely for commercial cars—except in so far as it is used with some form of spring wheel, hub, or rim, as just described. Similarly, the cushion tire is mostly used for electric cars, its use following that of the solid tire.

PNEUMATIC TIRES

The pneumatic tire was originally developed for bicycle use and in the beginning many single-tube tires were used. All of the tires used today have two parts—an inner and an outer tube.

Classification. Considering only the double-tube types, therefore, the pneumatic tire may be divided into three kinds: the Dunlop; the clincher; and various later forms brought out to go with the detachable demountable rims; and similar devices. These latter vary widely in themselves, but all are modifications of the clincher form, with minor differences of the difference in rims.

Dunlop. The Dunlop tire, so named after the Irish physician who invented and constructed the first pneumatic tire, is brought down to meet the rim in two straight portions, perfectly plain and of even thickness, that is to say, the tire has no bead, as it is now called. The tire fabric is brought down to a straight edge at the rim, as well as the rubber covering, as shown in Fig. 509. *A* is the steel rim of the wheel, *B* the inner tube, *C* the outer shoe, which at the rim or inner portion is brought down to the two straight parts *DD*.

This tire, like all of the early tires, had to be put on over the edge of the rim by sheer strength, coupled with the flexibility of the tire when not inflated. This was a hard task, and, moreover, as soon as the tire was punctured or otherwise deflated, there was a strong possibility of its being thrown off, and possibly lost, at east after it had been stretched on and off the rim a few times.

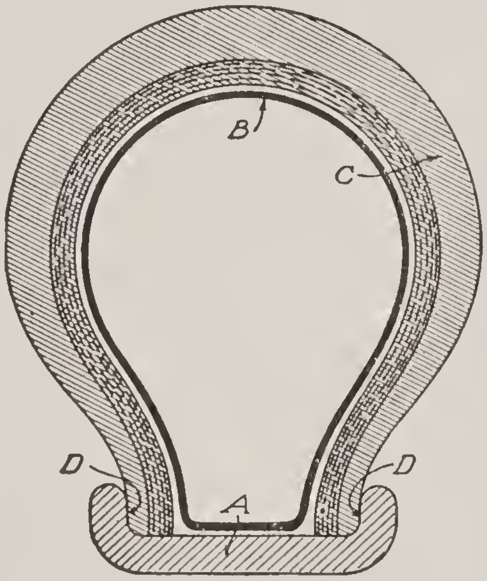


Fig. 509. Section of Dunlop Tire

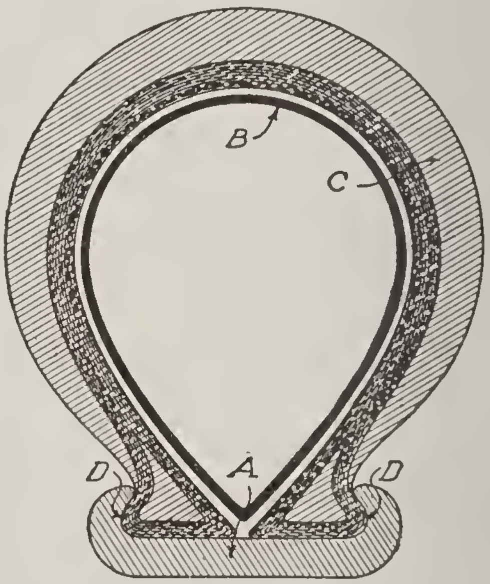


Fig. 510. Section of Typical Clincher Tire

Clincher. To prevent this latter happening, the clincher rim and tire were brought out, each being dependent upon the other. In the clincher tire, the fabric is brought down to the rim, and then, instead of being left straight out as in the Dunlop, the material is formed into a hump, or bead, which is shaped just like the hollow formed in the rim. The latter differs from the usual Dunlop rim only in having this deep depression to fit the bead of the tire. Fig. 510 shows this, in which the parts are lettered as before. In both cases, the fabric of the tire is sketched in, and it may be noted that the layers are fewer in number in the older form.

The great majority of tires now in use are of this type, although, like the original Dunlop, it must be forced on and off the rim by the stretch of the deflated tire, and by sheer strength, coupled in this case with considerable natural ingenuity and some tools for lifting the hard non-stretchable beading over the edge of the rim at one point. This done, the rest is easy. For this purpose many tools have been bought; some good, some bad, and some indifferent. After a fashion, all do the work, but that tool is best which performs the operation most easily, most quickly, and with the least damage to the tire or rim. Fig. 511 shows a useful tool for this purpose.

The wire wheel and demountable rims, both allow quick road changes of damaged tires, leaving the work of tire repair to be done at home in the garage with proper heat, light, tools, and materials. This is rapidly bringing back into use the lower price clincher and straight-side tire forms, also many new tools have made their removal or attachment a much easier and more simple task.

Demountable Rim Types. Following the development of the clincher tire and rim until this form of tire was practically universal, came the first forms of the demountable rims, which consisted of a detachable edge or rim portion, like the edge of the clincher rim in section. These were locked in place in various ways in the different forms, but the first demountable rims—they were called detachable rims—were made by cutting the clincher rims into two parts, one of them detachable. This allowed of slipping the tire on over the rim in a sidewise direction, and did away with the stretching and pulling necessary with the plain clincher. Since this was a tire which was detachable more quickly than the ordinary tire, it was given the name "Quick Detachable", and now both parts are known to the trade as the Q.D. tire and rim.

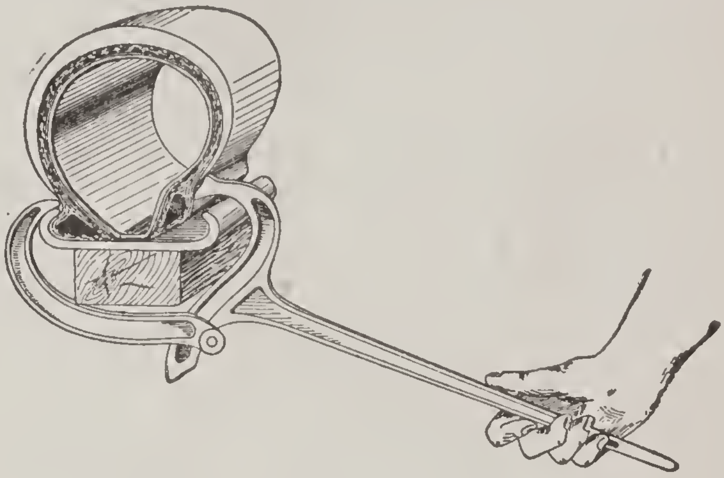


Fig. 511. Tire Removing Tool

Non-Skid Treads. All of the later developments in the clincher tire have been along the line of studded or formed treads to prevent skidding. In this many different things have been tried. Fig. 512 shows sections of many of the representative tires on the market. They are well known, and only the last three need any comment.

Fig. 512 *H* shows the Kempshall (English) tire tread, which is built up of a series of circular button-shaped depressions, or cups,

which hold the pavement by means of the suction set up when they are firmly rolled down upon it. This tire has been very successful in England, but as yet has not been used much in this country.

The Dayton Airless tire, shown in Fig. 512 *I*, is a bridge-constructed cushion tire in which the usual air space is given over to a series of stiffening radial pieces of solid rubber, these with the tread forming the bridge or truss. Fig. 512 *J* shows the Woodworth adjustable tread for converting the usual smooth-tread tires of whatever shape or form into non-skids. It is a leather and canvas built-up structure, shaped like the exterior of a tire, and freely studded with steel rivets. When in place, the tire has all of the appearance of a leather-tread tire with steel studs.

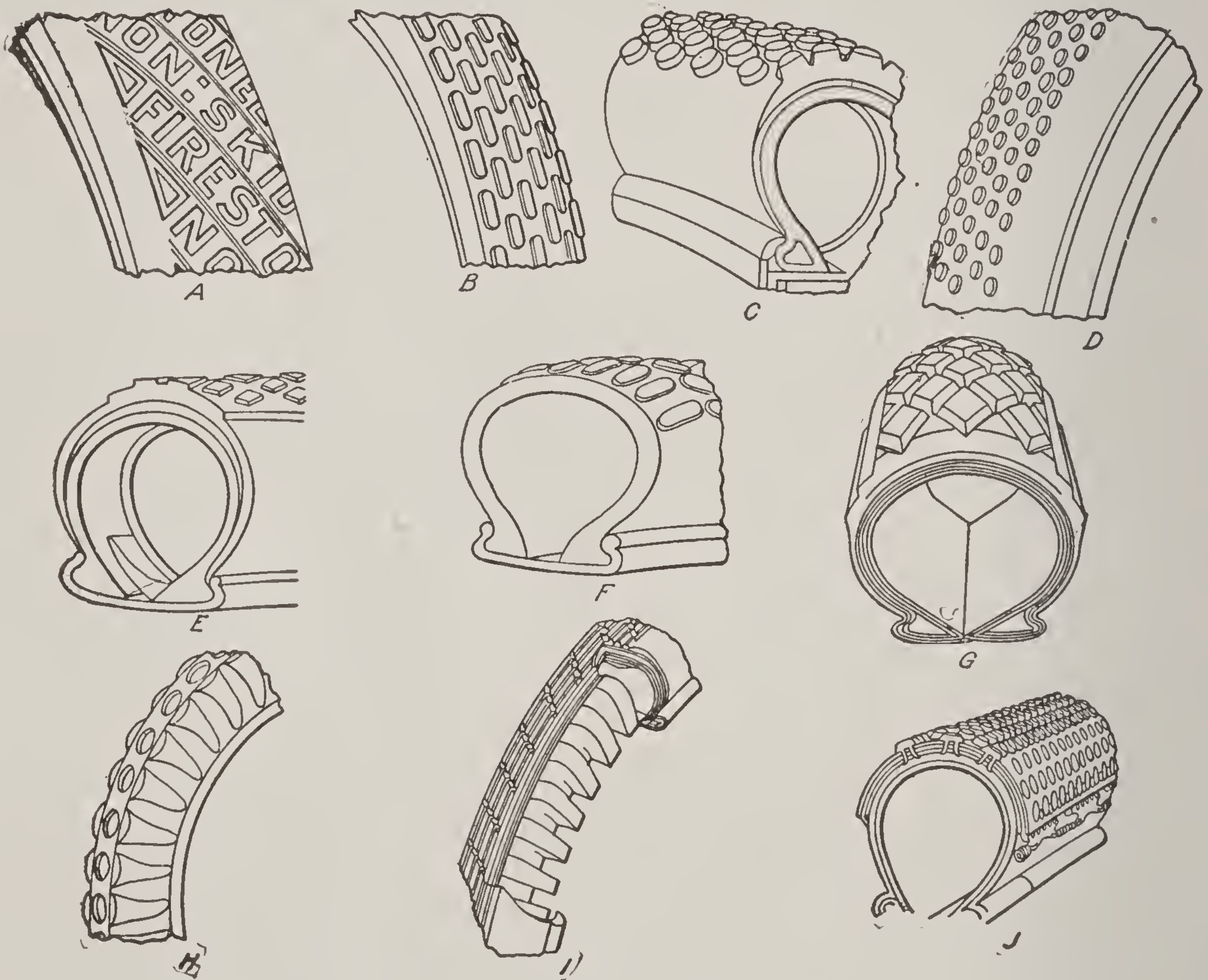


Fig. 512. Various Types of Non-Skid Tire Treads

Proper Tire Inflation Pressures. With the recent great increase in the value of rubber and the price of tires, the advice of manufacturers on the subject of tire wear is of great and growing importance. Nearly every manufacturer of tires is now recommending a table of inflation pressures which agree among themselves more or less closely. In each and every case, however, the makers are advising higher pressures than those generally used, stating that the people do not pump their tires up hard enough to get the best results from the materials in the tires. There should really be no conflict of interests here as the owner should be as anxious to get his mileage out of the tires as the makers are to make good their guarantees.

Many makers have stated, as a result of their years of experience, that more tires wholly or partially fail or wear out from under-inflation than from any other one cause. It thus behooves the owner of a car to look well to the pressure in his tires, not occasionally but very frequently. As the majority of gages attached to pumps in public garages are seriously in error, each motorist is advised to purchase his own gage—one of the pocket type which is simple and inexpensive—and carry it with him at all times.

In some cases, it will be found that pumping the tires up to the makers' specified pressure will result in unusually hard riding, and the motorist must be his own judge as to whether he wants to ride more comfortably and get less wear out of his tires or to put up with the discomfort and get every cent of wear out of them. In this matter, very few will choose the latter course.

Use of Standard Pressure and Oversize Tires. There is really a different way out. If the tire pressure advised by the maker results in too hard riding for comfort while comfortable pressures result in too much wear, the motorist is advised to get large size tires. These on the same car will have a greater carrying capacity than the weight of the car by a large margin. Just in the proportion of the tire capacity to the weight of the car will be the pressure recommended to the pressure utilized.

A simple example will make this clear: Suppose, for instance, a car weighing 3850 pounds, equipped with 34- by 4-inch tires, for which the makers claim a carrying capacity of 1100 pounds per wheel and recommend a pressure of 95 pounds. If this pressure be too high for comfort, and lower pressures, say 80 or 85 pounds, result in too rapid wear, the motorist should use larger tires. For instance, a 34- by 4½-inch tire is scheduled to carry 1300 pounds per tire, and the pressure recommended is 100 pounds. The car weight per tire is 962 pounds, say 970. Changing to the larger tire gives a capacity of 1300 pounds per wheel, while the load is actually but 970. This change provides a surplus capacity which can be utilized to increase comfort.

Hence, if the tire be pumped up in the ratio of the carrying capacity of the tires to the actual weight carried, the spirit of the manufacturers' instructions will have been followed, comfort assured, and long life of the tire attained as well. Here the ratio of the capacity to the weight is as 1300 : 970. If now the pressure be figured from this, using the 100 pounds recommended, a suitable pressure will be obtained. Thus

$$1300 : 970 :: 100 : x$$
$$x = 74.6 \text{ pounds}$$

The pressure, therefore, in round numbers will be 75 pounds, and if this or any comfortable pressure above this be used, only the proper amount of tire wear will result, and a comfortable riding car will be assured.

However, this proposition, namely, changing from 34- by 4-inch to 34- by 4½-inch tires, is one which calls for entirely new rims, and possibly entirely new wheels, or at least new felloes, because the bottom diameter of the 34- by 4½-inch is different from that of the 34- by 4-inch. In such a case as this, the motorist would gain by changing to a still larger size, say 35- by 4½-inch, which change can be made without disturbing the old rims, as the 35- by 4½-inch is an oversize for 34- by 4-inch. This size also is recommended to carry 1300 pounds at 100 pounds pressure per square inch, but maximum pleasure and comfort will be obtained from it at between 72 and 80 pounds.

In general, the rule for oversize tires is this: Oversize tires are 1 inch larger in exterior diameter and ½ inch greater in cross-section than the regular sizes, and any tire so sized will fit interchangeably with the regular size on the same rim. In general, too, the even-inch sizes, as 30, 32, 34, etc., are considered as the regular sizes, while the odd-inch sizes, as 31, 33, 35, etc., are considered as oversizes. The above is for American or inch sizes only. The foreign, or millimeter, tire and rim situation is in an even worse condition, and changes of sizes are difficult in all cases and impossible in most.

Changing Tires. In the matter of changing tires, care must be exercised in selecting the new tire of such a size as will fit the old rim. A larger section of tire of the same nominal outside, or wheel, diameter would call for a smaller rim diameter, meaning a change in rims and possibly wheels. A larger nominal outside diameter will change the speed of the car and, if great, may be too much for the engine, calling for new gearing as well. The following tabular matter will be of interest, as it gives the changes in the metric size tires which can be made without altering either wheel or rim or changing the gearing.

Possible Tire Changes

760 mm. × 90 mm.	wheels can be altered to.....	765 mm. × 105 mm.
810 mm. × 90 mm.	wheels can be altered to.....	815 mm. × 105 mm.
		and 820 mm. × 120 mm.
840 mm. × 90 mm.	wheels can be altered to.....	850 mm. × 120 mm.
870 mm. × 90 mm.	wheels can be altered to.....	875 mm. × 105 mm.
		or 880 mm. × 120 mm.
910 mm. × 90 mm.	wheels can be altered to.....	915 mm. × 105 mm.
		or 920 mm. × 120 mm.
815 mm. × 105 mm.	wheels can be altered to.....	820 mm. × 120 mm.
875 mm. × 105 mm.	wheels can be altered to.....	880 mm. × 120 mm.
		or 895 mm. × 135 mm.
915 mm. × 105 mm.	wheels can be altered to.....	920 mm. × 120 mm.
		or 935 mm. × 135 mm.
880 mm. × 120 mm.	wheels can be altered to.....	895 mm. × 135 mm.
920 mm. × 120 mm.	wheels can be altered to.....	935 mm. × 135 mm.

These can be used without changing the gearing or the wheels, but to use different tires without changing rims is another matter. It will, therefore, be necessary to have another table of the various tires which are interchangeable on the same rim. Of the makes which are fairly international in character may be mentioned the German "Michelin" and the French "Continental". The following Michelin tires may be fitted to the same rim, the two tires on the same horizontal line being interchangeable in each case:

Interchangeable Michelin Tires

650 mm. × 65 mm.	and	700 mm. × 75 mm.
700 mm. × 65 mm.	and	750 mm. × 75 mm.
750 mm. × 65 mm.	and	800 mm. × 75 mm.
800 mm. × 65 mm.	and	850 mm. × 75 mm.
700 mm. × 85 mm.	and	710 mm. × 90 mm.
750 mm. × 85 mm.	and	760 mm. × 90 mm.
800 mm. × 85 mm.	and	810 mm. × 90 mm.
860 mm. × 85 mm.	and	870 mm. × 90 mm.

The following tires of the Continental make are interchangeable on the same rims:

Interchangeable Continental Tires

750 × 75 (motor cycle) and 750 × 80 (voiturette)
750 × 65 (motor cycle) and 750 × 65 (voiturette)
800 × 75 (motor cycle) and 800 × 75 (voiturette)
700 × 85 and 710 × 90 (light and heavy)
750 × 85 and 750 × 90 (light and heavy)
760 × 90 and 700 × 100 (light and heavy)
870 × 90 and 810 × 100 (light and heavy)
910 × 90 and 910 × 100
820 × 100 and 820 × 125
880 × 120 and 880 × 125
920 × 120 and 920 × 125
815 × 105 fit only 105 mm. rims

NOTE. Although the 105 mm. tire requires a special rim, a 90 or 100 mm. cover can also be fitted on the same rim in the case of necessity.

810 × 90 or 810 × 100 fit on the 105 mm. rim
875 × 105 fit on the 105 mm. rim
910 × 90 or 910 × 100 fit on the 100 mm. rim
895 × 135, 935 × 135, and 1000 × 150 require their own special rims

Speed Changes Due to Changed Tires. Before leaving the subject, it might be well to say a few words concerning the change of speed which a change in tire sizes will make in a vehicle, this in some cases being so serious as to impair the utility of an engine formerly found to be right in every particular. In the course of a very wide experience, the writer has found this to be the case with many old cars. Using the old small wheels and tires, the engine was able to negotiate all grades easily and make the required speed at all times. With a change to larger wheels and tires, the car ran faster at all times and gave much more trouble generally. It also proved a poor hill climber, so much so, in fact, that the owner had to go one step further and change the gearing so as to give the old speed ratios before the engine again acted satisfactorily.

Recent Tire Improvements. There have been but three recent notable improvements in tires which are briefly discussed.

Tire Valves. There have been several kinds of troubles with the old form of tire valve. It was spring actuated, and the springs were so small as to cause much trouble; further, it had to be screwed in place, requiring a special tool. There are several new valve forms with more than one seat, and others with an improved seat designed to screw in with the fingers and to offer little or no resistance to inflation.

Inner Tubes. Improvement has been made in inner tubes by the use of better and purer rubber in much thicker sections. Some of these have a partial fabric reinforcement; others are made and then turned inside out so that the tread portion is under compression, thus resisting punctures or internal pressure. Other designs present a tube larger than the inside of the tire before inflation; this produces a truss formation of the rubber, which the air pressure stiffens.

Cord Tires. The real improvement of value, however, is the cord tire. One form of this is shown in partial section in Fig. 513. This shows graphically that the difference between this tire and other forms is that the 4 to 6 or more layers of fabric have been replaced by two layers of diagonally woven cord. This cord is continuous, rubber impregnated, rubber covered, and, through its size, allows a great and very even tension. Lessening the amount and thickness of the fabric has given a greater percentage of rubber in the tire; consequently, the cord tire is more resilient. The advantages claimed for it are: less power used in tire friction, which means more power available for speed and hill climbing; greater carrying capacity in same size; saving of fuel; greater mileage per gallon of fuel; additional speed; quicker starting; easier steering, thus less driving fatigue; greater coasting ability; increased strength; and practical immunity from stone bruises owing to superior resiliency.

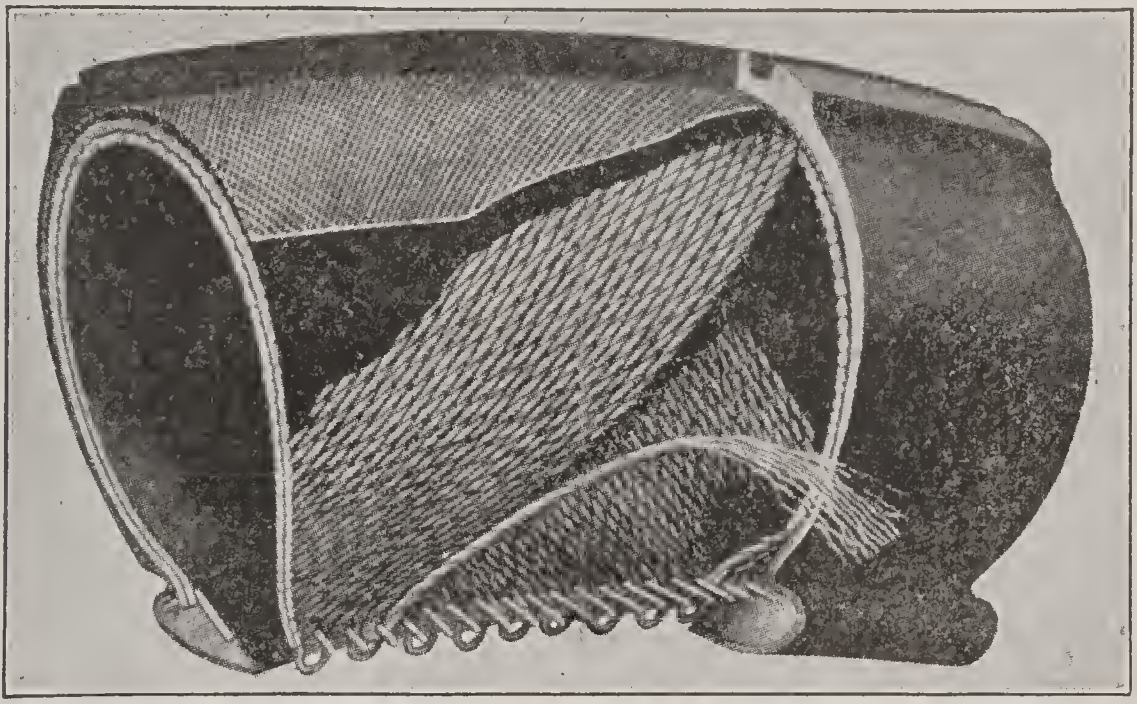


Fig. 513. Section of Goodrich Silvertown Cord Tire, Showing Inner Construction

RIMS

Kinds of Rims. Nearly all rims are of steel or iron, but vary greatly as to types. The writer has therefore chosen only a few of the well-known ones, no preference being shown in this.

Rims will be taken up in the order of their development. Naturally, the first rims were of the plain type, while the latest are of the demountable, remountable, or removable types, all these being very much the same. Between the two came the clincher rim, which is properly a plain rim; and the quick-detachable rim.

Plain Rims. The form of rim first used was naturally the solid type, shown with the Dunlop tire in Fig. 509. This form is a simple endless band with two edges just high enough to prevent the tire from coming off sidewise when it has once been stretched in place. Nothing like it is used today, the nearest approach being the form of rim used with single-tube bicycle tires.

Clincher Rims. Clincher rims were brought out primarily to avoid the weaknesses of the Dunlop, viz, a weakness at the base, and, hence, it had an unusually heavy bead. Another fault which this tire remedied was the tendency under high pressure for the tire to draw away from the rim. This was avoided by the edge of the clincher being made fairly wide where it was designed to go into the pocket, or groove, formed by the contour of the rim.

It is the depth of this pocket, or groove, and the corresponding size of the edge of the bead on the tire, both excellent qualities, which make the tire hard to put on and take off. This may be seen from the previous illustrations of clincher tires, notably Fig. 510.

Quick=Detachable Tire Rims. It was this inherent difficulty of handling the clincher tire and rim which brought about the quick-detachable tire. This did not differ from the clincher tire in the tire portion, the difference being in the rim, which has one curved portion made in removable form, with a locking ring outside of it or made integral with it. In some quick detachables, the rim is expanded by a special tool and a spacing piece set into place, which holds the edge expanded. When this is done, the ring—as it is a simple ring with special ends—is held in place until released by the use of the special tool. On the end of the ring there are two little square lugs which project downward and have a hook shape. The one edge of the rim, made flat and straight on that side, has a slot with staggered, rectangular ends into which these lugs fit. It requires force to spring the rings together so the lugs will go into the slots, but once in place, the natural springiness of the rings holds them firmly in place, and holds the tire as well.

Figs. 514, 515, and 516 are given to show how this ring is put in place on a tire. Fig. 514 shows the beginning of the operation, and the instructions for the different steps will make them clear. Thus:

> Always start with left end of the ring. Lock this in the rim as shown in Fig. 514, so that the end of the ring is flush with the slot provided for the second end. A dowel pin is provided to register the ring in the proper place. This must always be correctly centered or the ring cannot be applied. This done, the balance of the ring can be forced over the flange of the rim, as shown in Fig. 515, with the exception of the locking end. By means of the tool, the last locking end can be raised and forced over the rim into the recess provided for holding the same in position preparatory to drawing the ends together, Fig. 516, showing the correct position of the tool.
>
> Then by entering the two points of the tool in the holes provided in the ring, the ends may be drawn together, as shown in Fig. 516, and, with a slight additional leverage, the ends of the rings can be made flush.

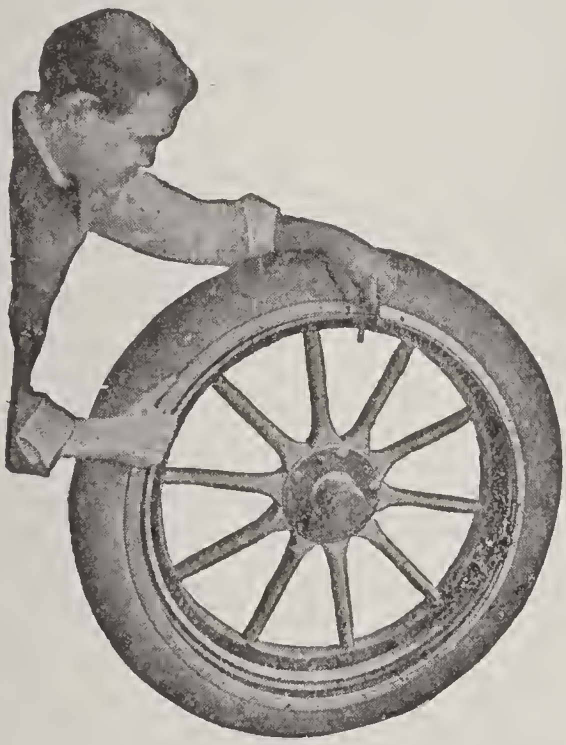


Fig. 514. Putting on a Q.D. Tire. The Start

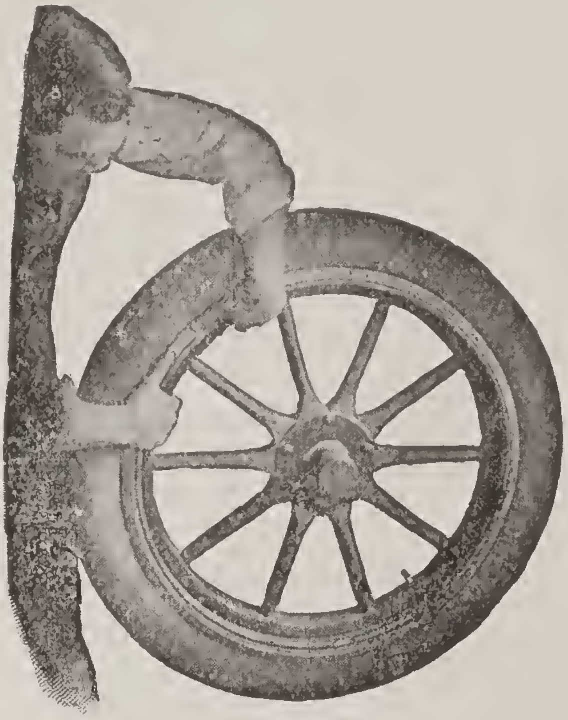


Fig. 515. Putting on a Q.D. Tire. Forcing Flange over Rim

Before proceeding further, it should be stated that the object of the quick-detachable rim is the quick removal of the tire, in order to allow a quick repair or substitution of the inner tube. On the other hand, the object of the demountable, remountable, removable, and other rims is the removal with the tire of the rim itself to allow the substitution of a new tire and rim, the tire being already inflated and ready for use as soon as applied. The object of the removable wheel is the removal of the entire wheel with rim and tire in order to substitute a spare wheel with already inflated tire.

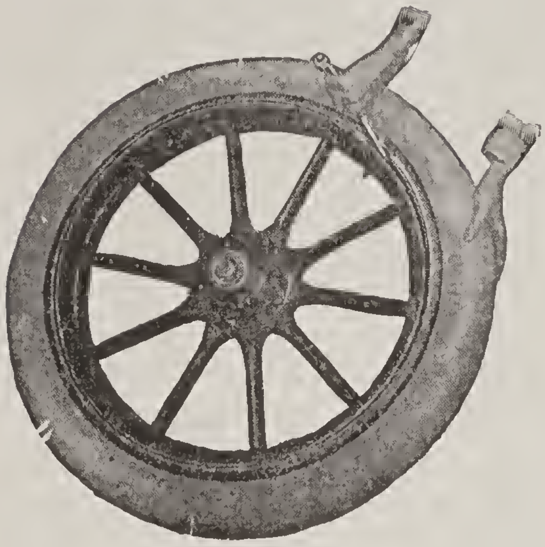


Fig. 516. Putting on a Q.D. Tire. The Locking Ring

It might be thought that these methods called for the carrying of extra weight, but the amount added is actually very small, as, by their use, tire tools and pump are dispensed with and their weight saved.

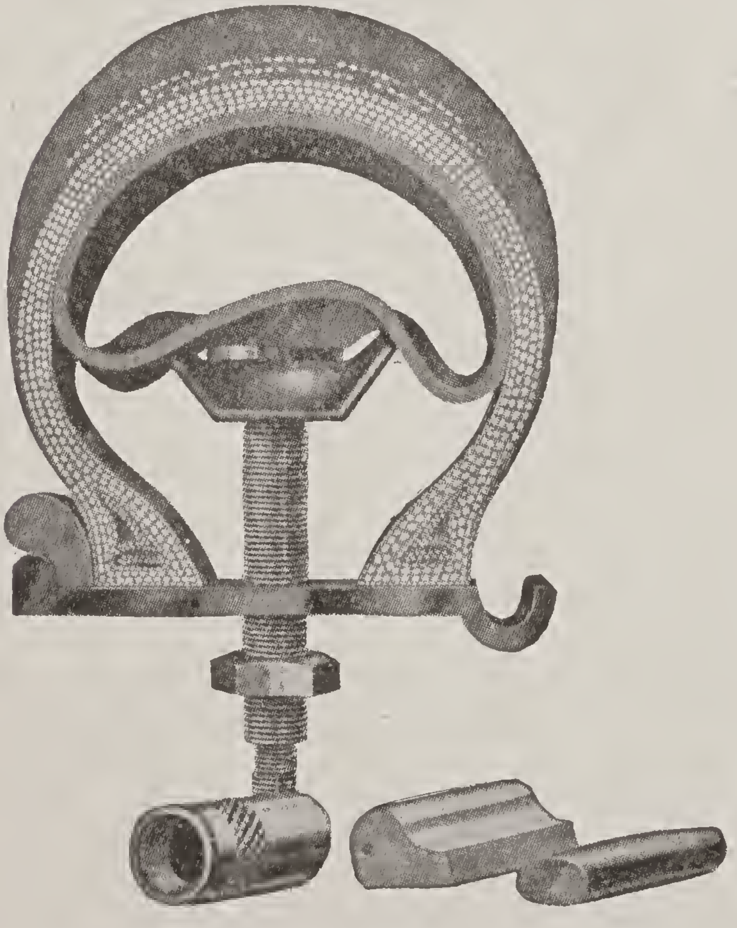


Fig. 517. Former Goodyear Universal Rim

Fig. 517 shows the former Goodyear rim. This rim, as will be noted, is of the quick-detachable type, the idea being to remove the tire only. The rim itself has a button-hook shape with a slight ridge, or projection, answering to the handle. This is on the fixed side, the inner flange inside of the tire butting against it as a stop. The tire is pushed over against this, being held on the outside by a second flange of similar shape. The latter, in turn, is fixed in place by a locking ring, a simple split circular ring of deep oval section. This fits into the button-hook portion, its contour being such as to fit it exactly. In use, it is sprung into place, the outer edge of the hook on the rim and the natural spring of the ring preventing it from coming out. This makes a very simple and serviceable quick-detachable rim. To make doubly certain that the locking ring cannot jump out, a spreader plate is attached to the valve stem; screwing this down into place wedges the bead of the tire over against the outer flange, which, in turn, pushes the locking ring tight against the outer curved part of the hooked rim. When in this locked position, the upper part of the flange hangs over the locking ring, so that it cannot rise vertically, the only manner in which it could come off. This rim is shown with a detachable tire in position, but may be used with any standard clincher tire by the use of extra clincher flanges. Fig. 518 shows the rim with a set of these flanges in position, ready to take a standard clincher tire.

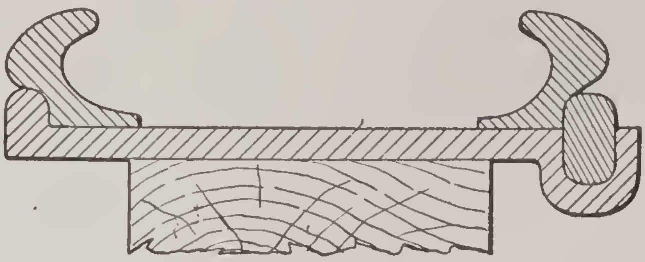


Fig. 518. Adapting Goodyear Rim to Clincher Tires

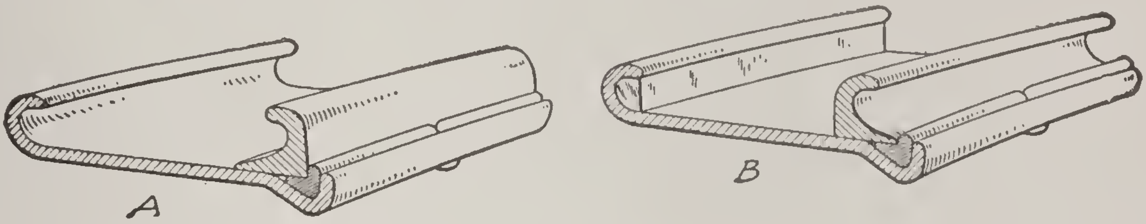


Fig. 519. Universal Q.D. Rim No. 2 Arranged for Clincher and Dunlop Tires

Quick-Detachable Number 2. Figs. 519 and 520 show the standard quick-detachable rim, now known as No. 2. This was adopted by the Association of Licensed Automobile Manufacturers

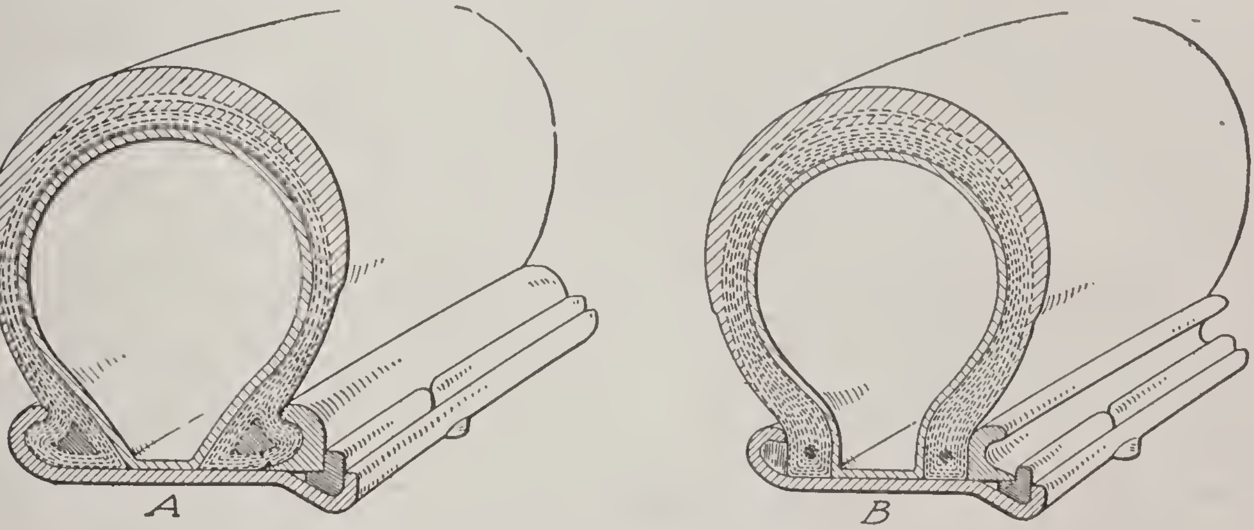


Fig. 520. Universal Q.D. Rim with Tires in Place

as a standard and given the above name. It has the feature of accommodating all regular clincher, or Dunlop tires. In Fig. 519, it is shown at *A* ready for a clincher tire and at *B* ready for a Dunlop tire, the adaptation for the straight sides being shown.

The two parts of Fig. 520 show sections of tires in place, making clear the exact use of this reversible flange. *A* shows a regular clincher tire in place, while *B* reveals the reversed flange in place with a Dunlop tire. Both Figs. 519 and 520 show the construction of the device, the outer dropped portion of the rim having a hole through it. The locking ring is split vertically and one end, just at the split, carries a projection or dowel pin extending downward. To put the rim on, this dowel pin must be fitted into the hole in the rim to give a starting place. When this has been done, one may force the balance of the ring into place around the wheel with any suitable, thin, wedge-shaped tool.

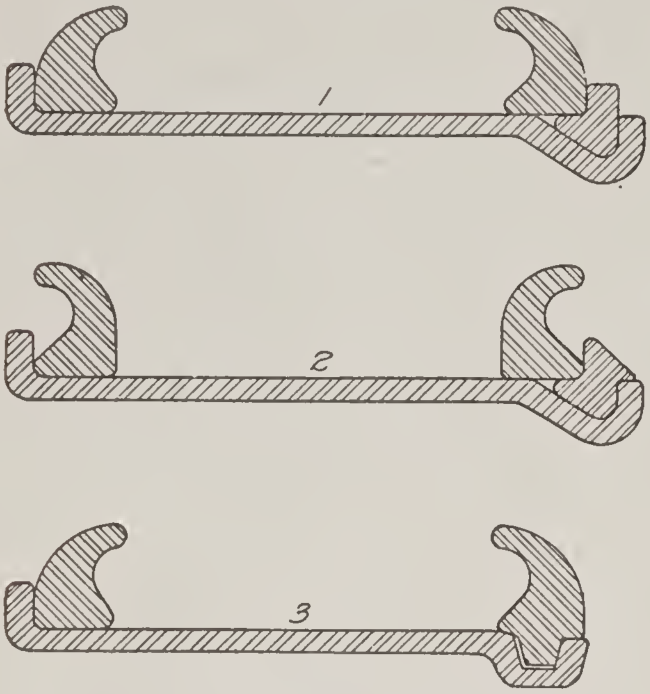


Fig. 521. Sections through Three Popular Q.D. Universal Rims

The shape of this locking ring with a right-angled groove in its inner edge permits the outer flange to overlap it, which insures the retention of the ring when once it has been put in place. Furthermore, it gives the outer side flange a wider seat on the rim, thus making it more stable and longer wearing.

As will be noted, the difference between these two rims—that is, the old Goodyear and the Universal No. 2—lies in the saving of one ring and the shape of the locking ring. Both of these are called universal rims because they may be used interchangeably for straight-side and clincher types of tire. Other Q. D. Universals are shown in Fig. 521, although, in the opinion of tire men, the Universal form is slowly going out of use.

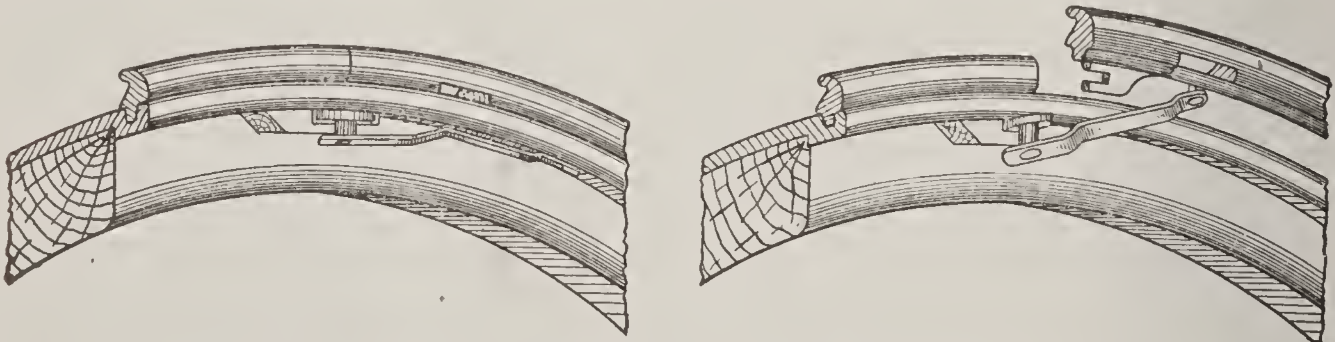


Fig. 522. Latch Used for Locking Single Combination Ring which Replaces Former Side Ring and Locking Ring

To explain these briefly, No. 1 is a modification of the Goodyear, with different shaped inner rings, while the locking ring and the lip formed in the felloe band to receive it are similar to those of Universal No. 2. In *2* the only difference from *1* lies in the locking ring, which has a modified **Z**-section, with a lip extending over the outer edge of the felloe band. The third section differs from the other two only in having the outer ring and locking ring combined into one, and the felloe band changed to suit this. This combination ring is held in place by means of a simple swinging latch, which is shown open and closed in Fig. 522. When opened, this permits raising the end of the ring, to which the shape of the felloe band offers no resistance. The whole inner ring is taken off, following around the circumference of the wheel, after which the tire is easily removed.

Quick-Detachable Clincher Forms. To return to the plain clincher tire and the Q. D. rim, which allows of its ready removal, Fig. 523 shows four of the most prominent forms, these being indicated simply as flat sections of the rim, for the tire is the same in all cases. All these have the simple clincher edge on one side, with removable ring and locking device on the other. That at *1* has the same locking device shown at *2* in Fig. 521, the **Z**-shaped ring extending over the edge of the band. That at *2* is practically the same as *3* in Fig. 521. The one seen at *3* is similar to that at *2* except for the detailed shape of the ring as well as the lock (not shown). The advantage of the form shown at *4* is that the outer ring is self-locking, that is, the shape of ring and band are such that when the former

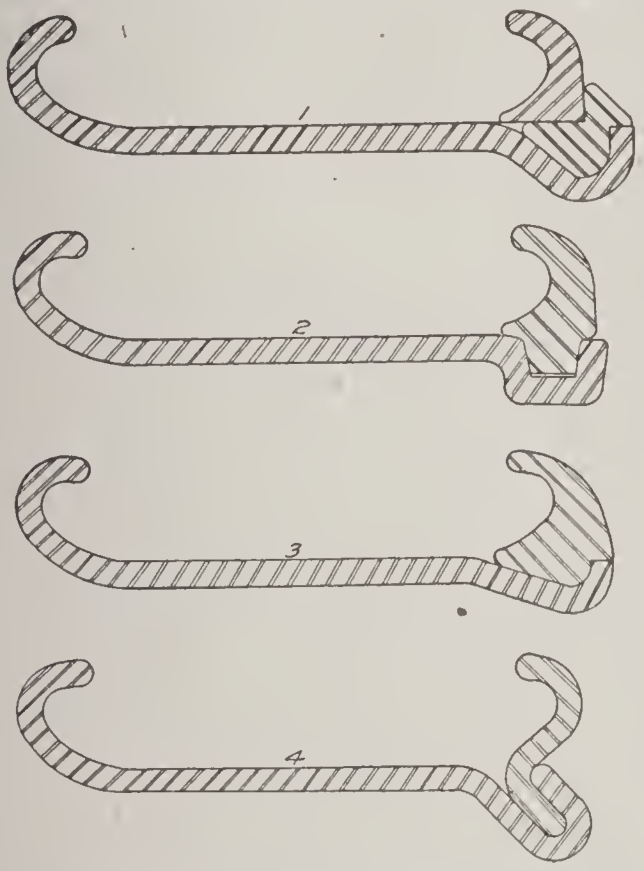


Fig. 523. Popular Forms of Q.D. Clincher Rims, Shown in Sections

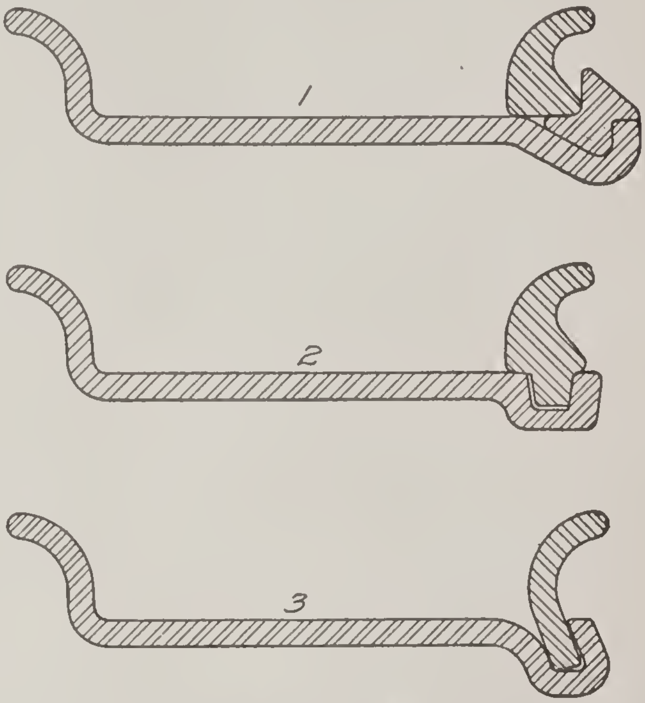


Fig. 524. Three of the Most Widely Used Straight Side Q.D. Rims

is in place the tire itself locks it. Its only disadvantage is that it is harder to operate than the other forms, yet despite this fact it has been recommended for general adoption as the only Q.D. clincher rim worth continuing.

Q.D. Type for Straight Sides. To close the subject of straight side tires, the rims of the quick-detachable form now in use aside from those already shown are seen in Fig. 524. Here these are seen to be identical with *1*, *2*, and *4* of Fig. 523, except that the fixed side is arranged for a straight side instead of being made with a clinch. Here again, the last form of self-locking type has been recommended as a standard.

Demountable Rims. All, or practically all, demountable rims come under one of two headings—those in which the tire can be detached on the wheel without demounting (if it is so desired) and those which are of the transversely split type and must be demounted before the tire can be removed. In addition, there is a second division of demountable rims into those which have a local-wedge form of attachment and those which have a continuous holding ring, this, in turn, being held by means of local wedges. Any of the plain demountables, which will be called demountables from now on, may be of either type of attachment, as is also the case with the first-named or demountable detachables.

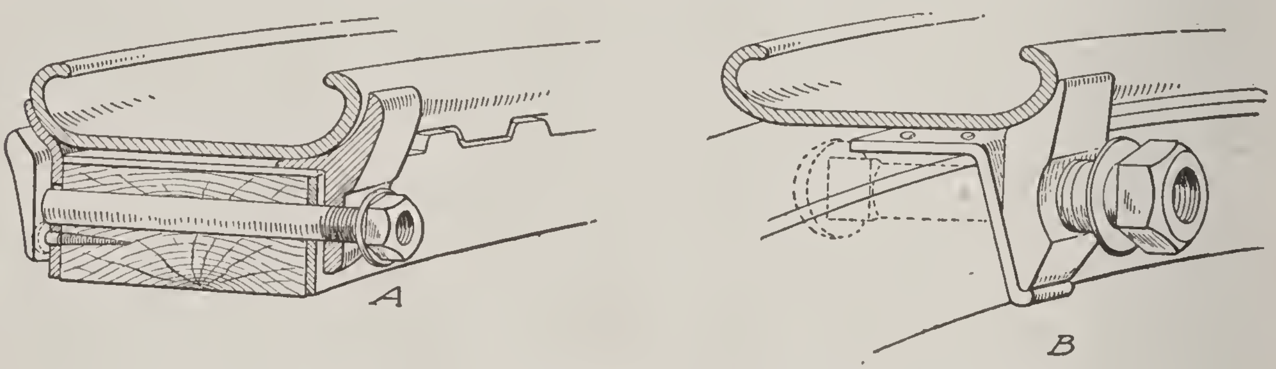


Fig. 525. Sections of Michelin and Empire Demountable Rims

Local Wedge Type. In the so-called local wedge type, which includes the well-known Continental forms (notably Standard Universal Demountable No. 3 and Stanweld No. 22 and No. 30), Michelin, Empire, Baker, Detroit, Prudden, Standard Universal Demountables No. 1 (formerly the Marsh), and No. 2, and others, loosening the six (or eight, as the case may be) bolts frees the rim directly without further work. In some of these, such as the Michelin; the various Continentals, including Stanweld No. 22 and No. 30;

Detroit; Baker; and others, the wedges carry a projecting lip, which makes it necessary to unscrew the nuts far enough to allow the removal of the wedge so as to pick this lip out from under the tire-carrying rim. In others, such as Empire, S.U. No. 1 and No. 2, the construction of the wedge and rim is such that loosening them frees the rim, the upper part of the wedge or clip swinging down to the bottom position as soon as loosened, because of its heavier weight and the fact that there is no projecting edge to prevent it. While this latter construction makes a faster operating rim, it is an open question as to whether it is as safe as the other form. These two constructions are shown very plainly in Fig. 525, in which *A* is the Michelin with lipped wedges, and *B* the Empire with plain wedges.

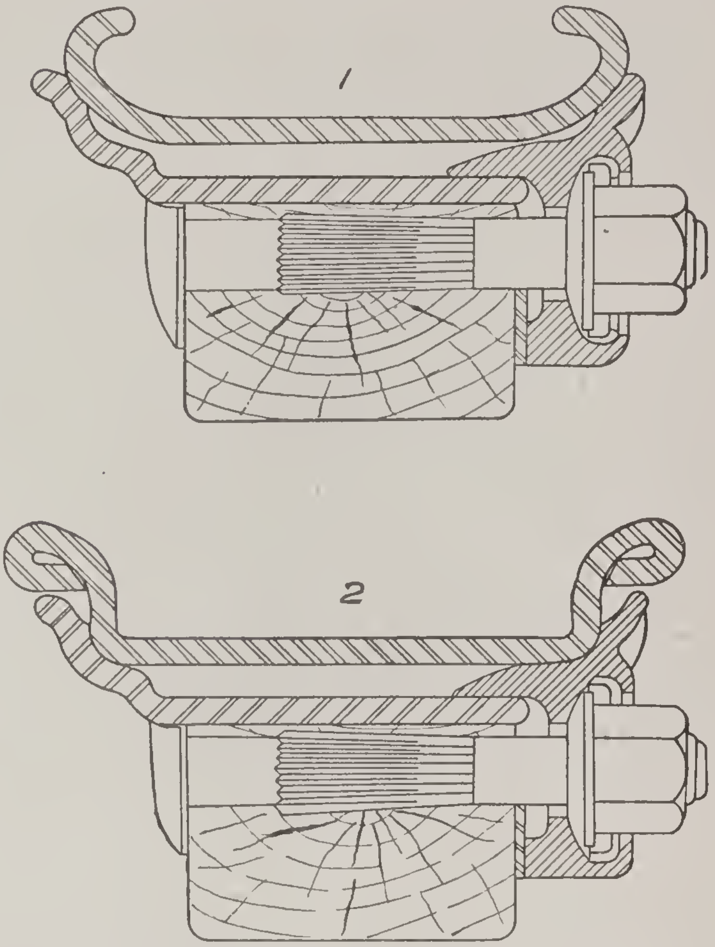


Fig. 526. Two Popular Demountable Rim Forms —for Clincher Tires above, for Straight Side below

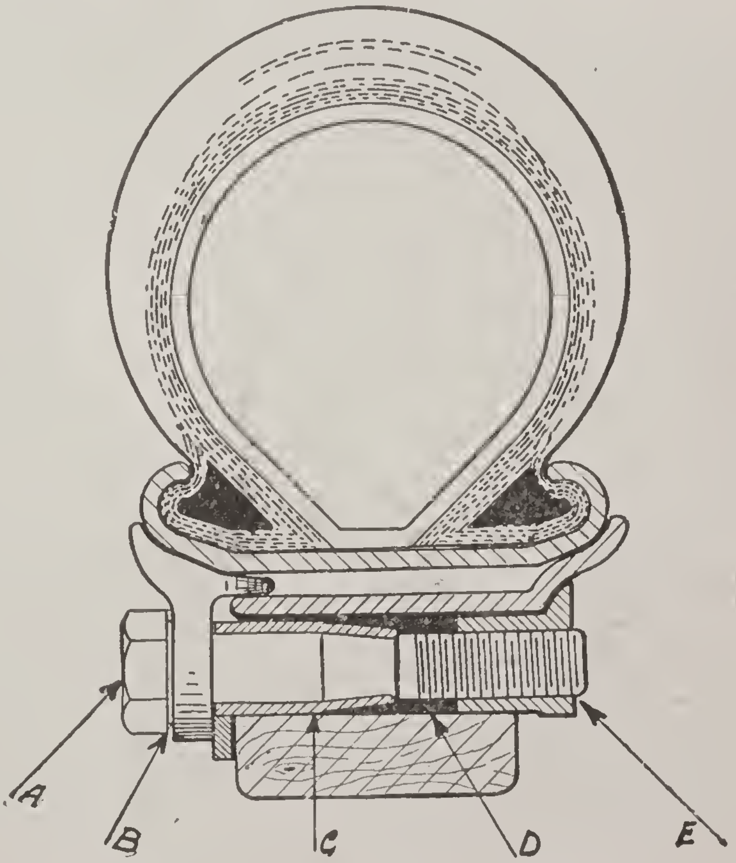


Fig. 527. Sectional Drawing Showing Construction of Baker Demountable Rim

In Fig. 526 is shown a pair of additional demountables, which are held by the local wedge method, the difference here being in the form of a wedge. Note that *1* has a solid clincher rim and *2* a straight side rim. The base, however, is the same for both and, as will be seen by examining this, has two curves in its upper surface, the straight side rim fitting into the lower or bottom one, while the clincher form of rim fits into the upper one. Note, also, that the wedges are the same for these two. This makes the demountable parts of the rim practically universal in that the owner can change from clincher to straight side or *vice versa* by simply purchasing the extra set of tire-carrying rims, no change in the wheels or means of attachment being necessary. For this reason, the felloe band shown under these two rims has been suggested as a standard for demountables.

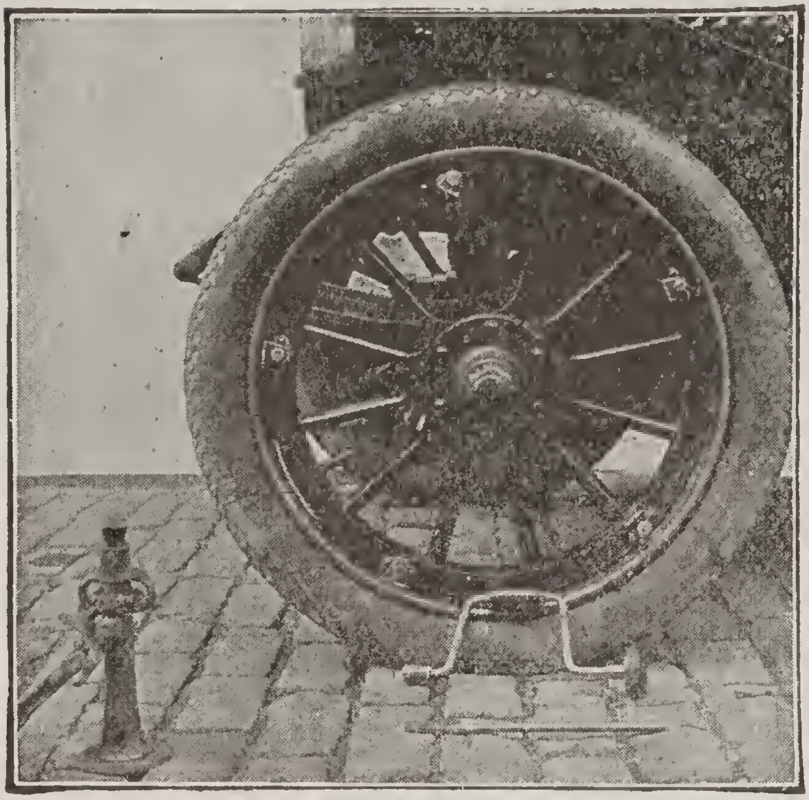


Fig. 528. The First Operation in Removing Baker Demountable—Loosening the Bolts

Process of Changing Baker Local Wedge Type. In Fig. 527 is shown the Baker, which, as mentioned previously, is of the local wedge type of demountable, having a transversely split rim which must be removed from the wheel before the tire can be taken off. Perhaps this whole action will be shown more clearly by the progressive series of views, Figs. 528 to 538, which show the various steps in removing and replacing a tire and tube mounted on a Baker rim, the same as is shown in section in Fig. 526. First, all the wedge bolts except the two nearest the valve stem, one on either side, are loosened by means of the special brace

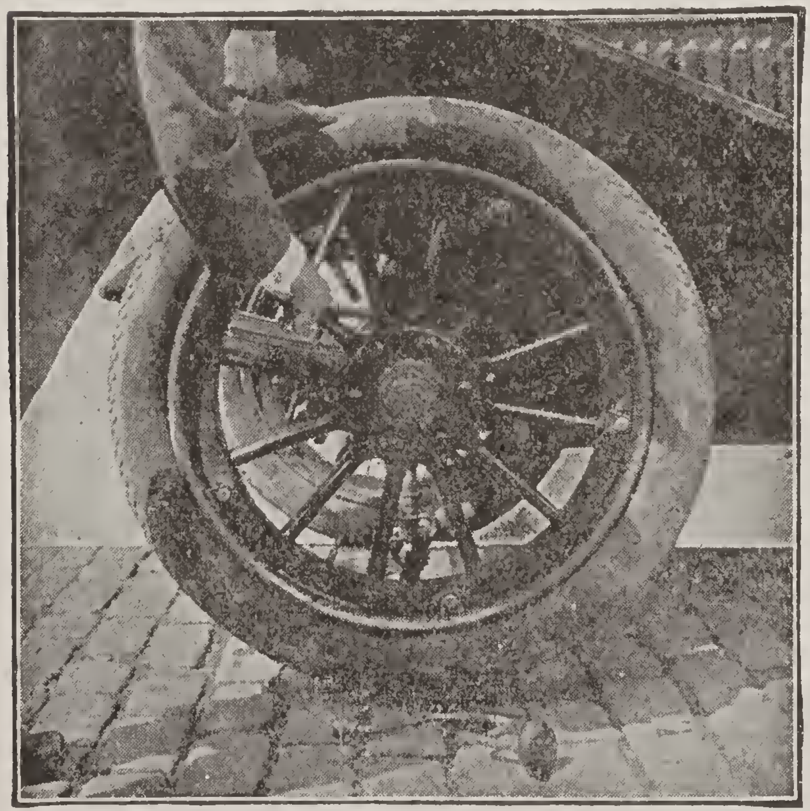


Fig. 529. Second Baker Demounting Operation—Jacking the Wheel and Starting to Pry off Rim

until the wedges swing out and down, as shown in Fig. 528. As mentioned previously, this means quite a little loosening, for the wedges have a long lip which projects under the tire-carrying rim. When this has been done, and as each one swings down out of the way, it is tightened just enough to prevent the wedges from swinging back.

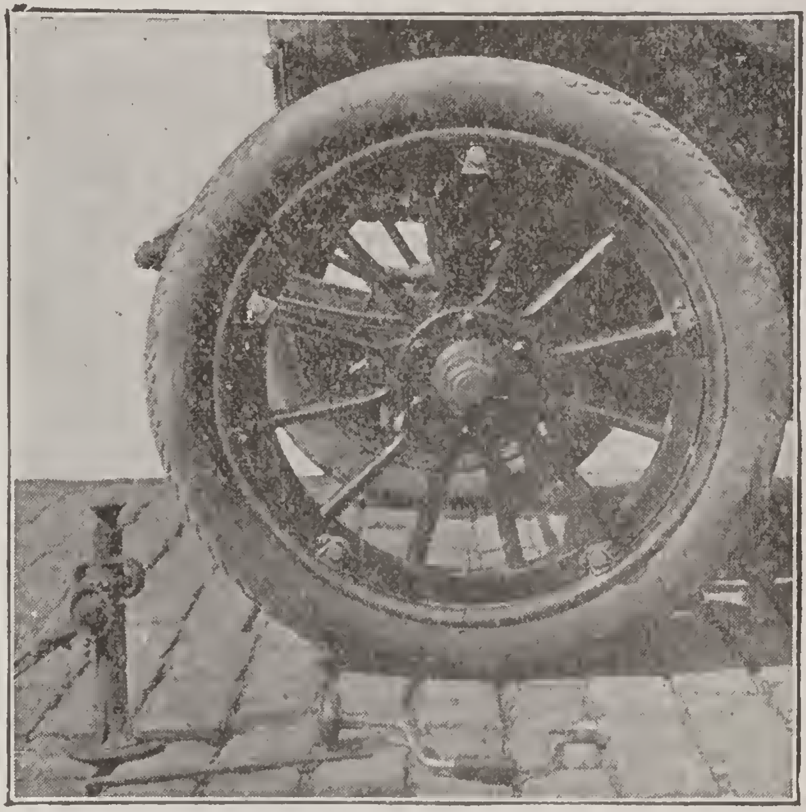


Fig. 530. Third Baker Operation—Putting on New Tire and Lowering Wheel

This done, the wheel is jacked up off the ground, as shown in Fig. 529, and the point of the tire tool is inserted between the felloe band and the rim carrying the tire at the point opposite the valve, where, it will be remembered, the wedges were loosened, and the rim will be almost free. By prying the tire-carrying rim outward and working around it toward the valve and back again, it will finally be loosened to a point where, with the valve at the bottom, the rim and tire can be slipped off without lifting it. The extra tire and rim are now put in place.

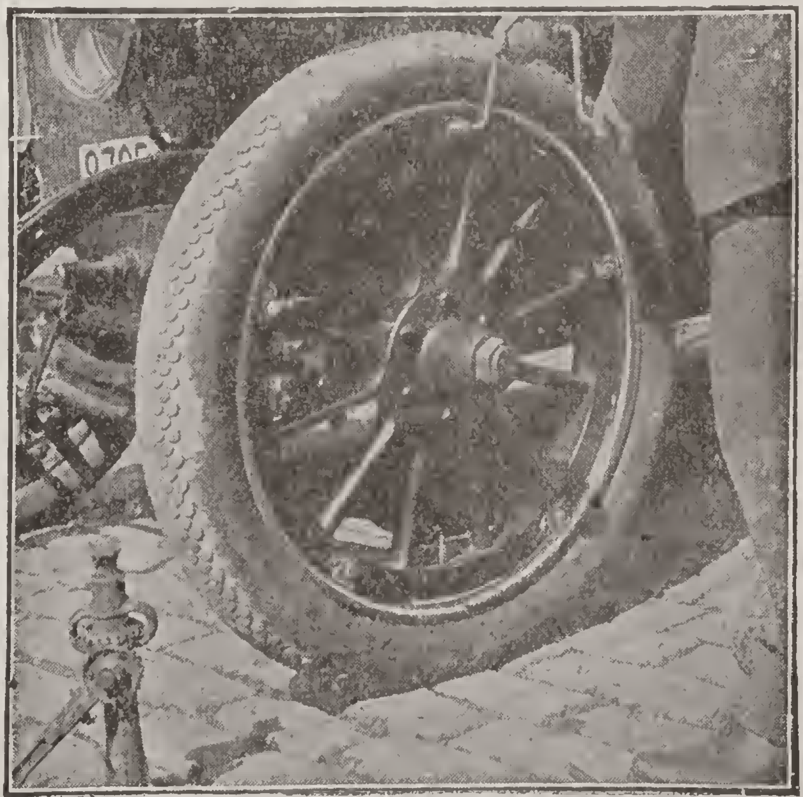


Fig. 531. Fourth Operation—Tightening Bolts on the New Tire and Rim

This is shown in Fig. 530, where the reverse of the operations shown in Fig. 529 and just described is followed, that is, the valve stem hole is revolved to the top, the valve stem inserted, the rim pressed into place all around, then the wheel is revolved until

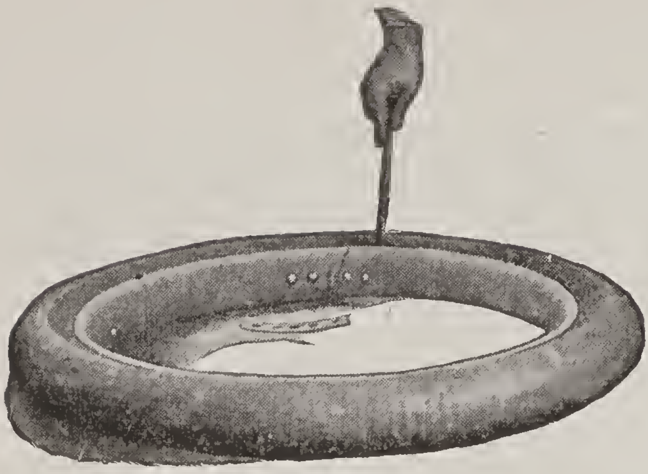


Fig. 532 Fifth Operation—Starting to Take the Rim out of the Tire—Beginning to Pry Short End

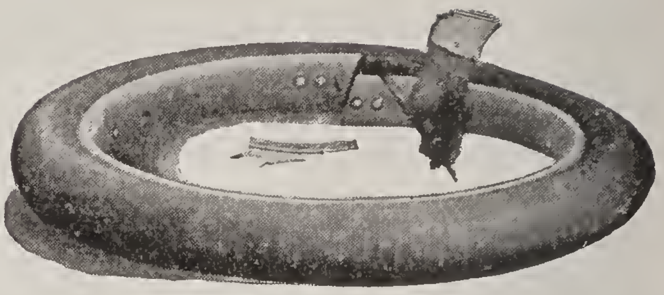


Fig. 533. Sixth Operation—Forcing Down the Short End of Rim

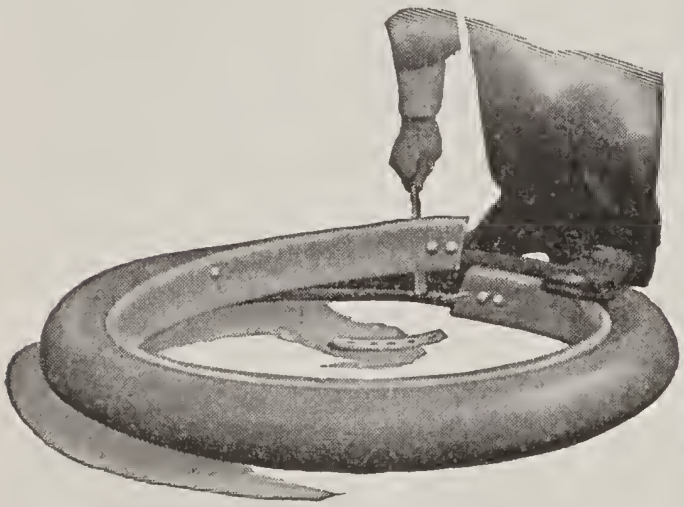


Fig. 534. Seventh Operation—Prying under the Loose End of Rim

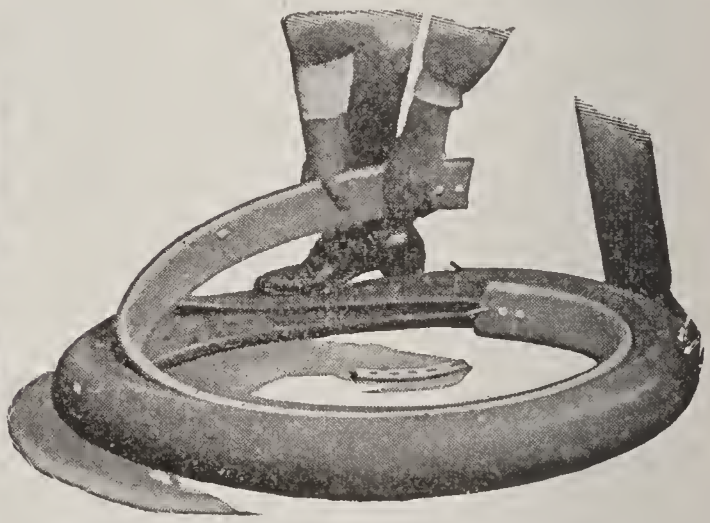


Fig. 535. Eighth Operation—Raising the Free End of Rim, Using Both Hands

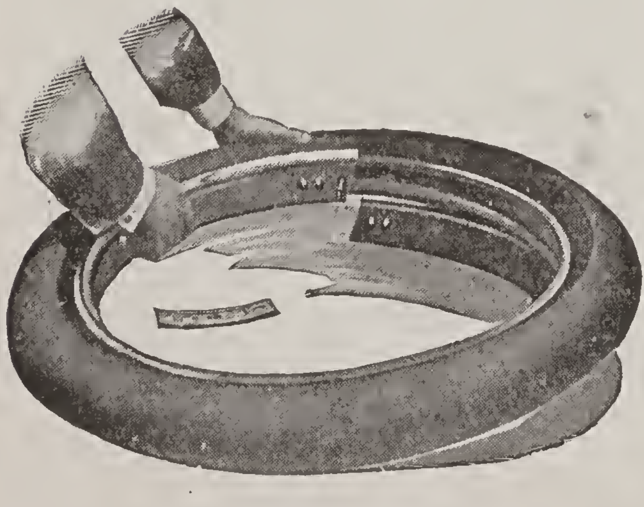


Fig. 536. Ninth Operation—Inserting Valve Stem and Beads in End of Rim

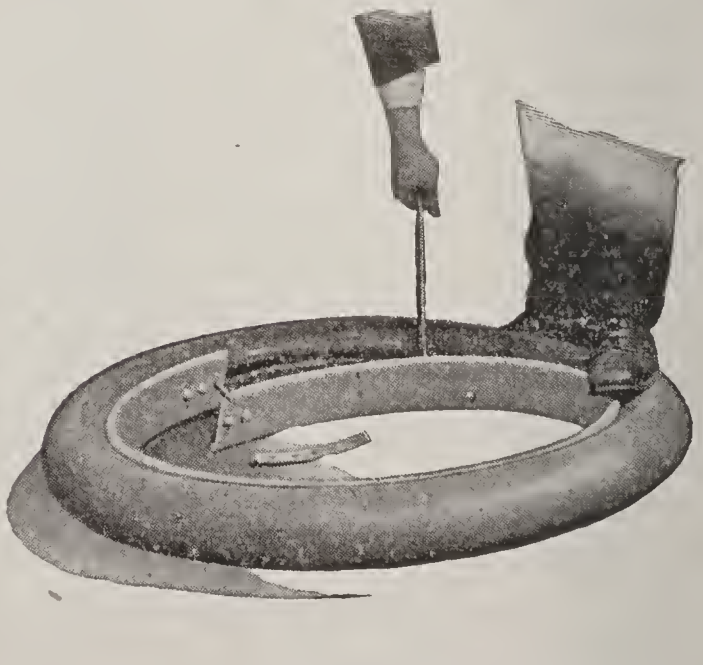


Fig. 537. Tenth Operation—Prying Tire Away from Rim to Let Latter Slip into Place

the valve stem comes to the bottom, so that the two wedges which have not been loosened are nearest the ground. Then the jack is let down and removed, the whole weight of the wheel coming on the bottom point where the wedges are already tight, never having been loosened.

This action is necessary as, with the weight on the other points where wedges are still loose, it would be necessary to work against the car weight. At this point, as Fig. 531 shows, the nuts are loosened, using the special brace until the wedges can be inserted under the rim. This done, the nuts are tightened to hold them there. This tightening is continued until the little studs, or lips, in the rim rest on top of the outside edge of the felloe band, using the tire tool to force them in, if necessary. The new tire carried is supposed to be ready for use, that is, inflated to the proper pressure, so that these four actions complete the work of making a roadside change.

When it is desired to repair the tire which has been removed, it is carried home on its rim just as taken off the car wheel, and the rim is removed from the casing as follows: Rim and tire are laid flat on the garage floor, as shown in Fig. 532, so that the outer end of the diagonal cut in the inside of the rim which is farthest from the valve stem is uppermost. An inside plate will be found on the rim which covers the two rivet heads on either side of the cut, with a central hole for the valve stem. This plate is called the anchor plate and must be removed. To do this, begin at the short end of the rim, which does not have the valve stem—as, in this position, it will be held in the long end—and insert the sharp end of the tire tool or a screwdriver under the bead or between the bead and the rim.

These two actions, as shown in Fig. 533, bring the two short sides of the rim closer together and thus reduce the diameter. When the extreme end has been freed in this way, the operation is repeated some 5 or 6 inches farther around, that is, that much farther away from the slit. This done, a considerable portion of one end will be free. Then turn the rim and tire over so that this free part comes at the top instead of at the bottom and, standing on the part which is still tight, insert the tool between the rim and the entire tire.

This frees the entire end, but, to make sure, the tool must be moved a little farther along so as to free more of it. When enough has been freed to allow grasping it with both hands, as shown in Fig. 535, the tool is dispensed with and, taking a firm grip on the rim, at the same time standing on the tire at the point where tire and rim still contact, pull upward strongly. When followed all the way around this pulls the rim entirely out of the tire.

Having the casing and tube free, they may now be inspected and repaired. When this is done, or if it is not done, and a new tire or tube or both are used, the worker is ready now to replace the rim. This is practically the reverse of the method just followed out. As shown in Fig. 536, the rim is laid on the floor; then the end which has the valve-stem hole drilled in it is raised, and the valve stem inserted. Next the beads are pulled into the rim, it being necessary to press them together somewhat tightly in order to do this, but, with a little practice, it soon becomes an easy matter. All this is done with the other part of the rim underneath the tire.

The inserted end of the rim is followed around with the thin end of the tire tool, as shown in Fig. 537, the position of the tire above the rim allowing the workman to stand on it and thus use his weight to press the two sides of the tire together and, at the same time, to force them into the rim. This operation is followed right around the inside circumference of the tire, the free, or short, end of the rim being the last part to enter. On account of the shape of the joint or cut in it, this should slip readily into its proper place, but if it does not, the thin end of the tool can be used to pry it into place, or a hammer can be used on the longer side to drive it in.

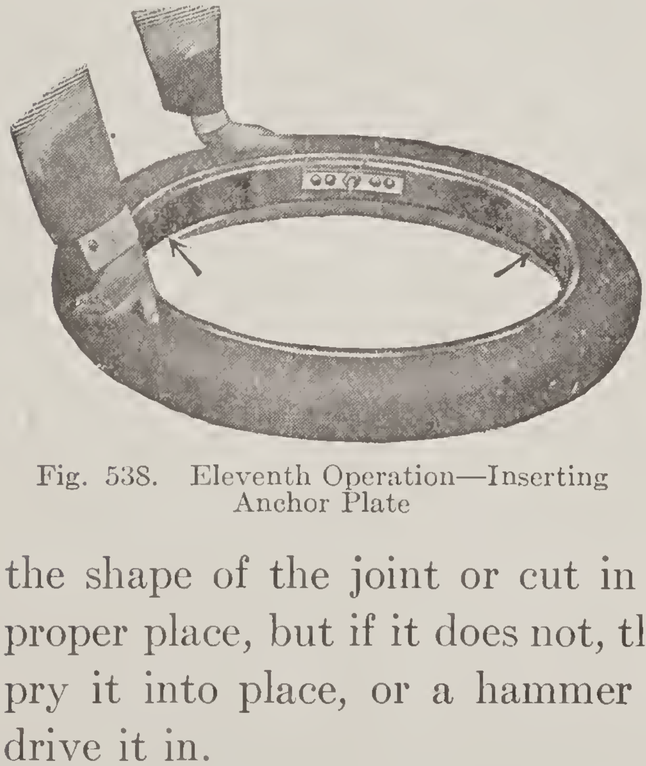


Fig. 538. Eleventh Operation—Inserting Anchor Plate

The rim being fitted snugly into place all around, the anchor plate is inserted, Fig. 538, to prevent the short end slipping out again, and the tire is ready for inflation. If it is to be carried as a spare tire, the dust cap should be screwed into place over the valve stem, so as to preserve the threads which might be damaged in handling.

Rim with Straight Split. This covers the action of practically all the demountables in which the transversely split rim is used, necessitating the removal of the rim and tire from the wheel before the tire can be taken off the rim. However, not all rims are split on a diagonal as is this one, and Fig. 539 is presented to show this single feature on another rim, which otherwise is somewhat similar. Here the rim is split at right angles, having a plain thin rectangular plate *A* attached to the free end, or that which is removed first, while the other end has a swinging flat tapered plate with a cam-shaped end *B*, the action of which is to expand the rim to its fullest diameter and lock it there. In the top figure, it is locked—that is, the rim is expanded as it would be when in use and just after it had been removed for replacement. When the rim is to be removed from the tire, the latch *B* is swung out of the way, as shown in the lower figure, when the catch *C* which holds the two ends together can be opened by lifting the tire with this portion at the bottom and then dropping it a couple of times. This done—usually this action will be accompanied by the free end spring inside the fixed end—continuation of the removal is an easy matter. The rim shown is the Stanweld No. 20.

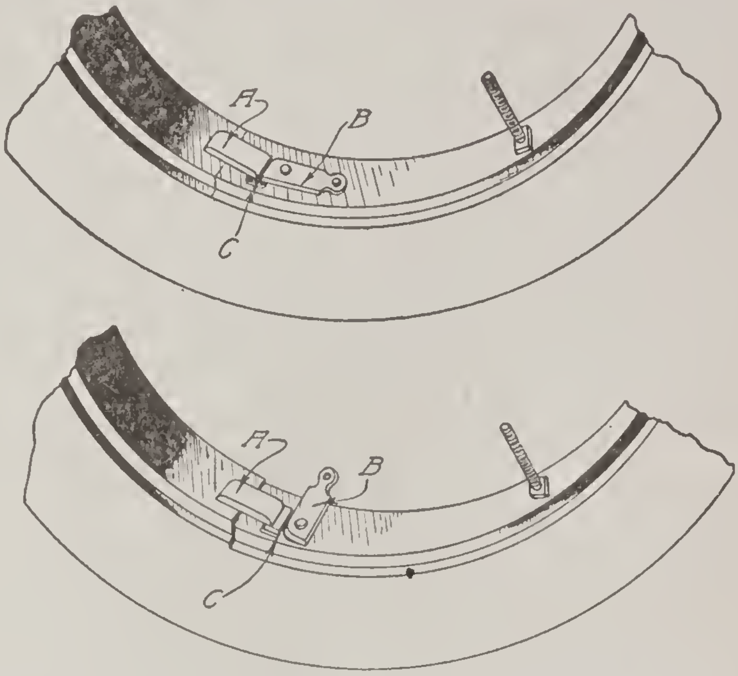


Fig. 539. One-Piece Rim, Showing Right-Angled Split and Locking Device

Courtesy of Standard Welding Company, Cleveland, Ohio

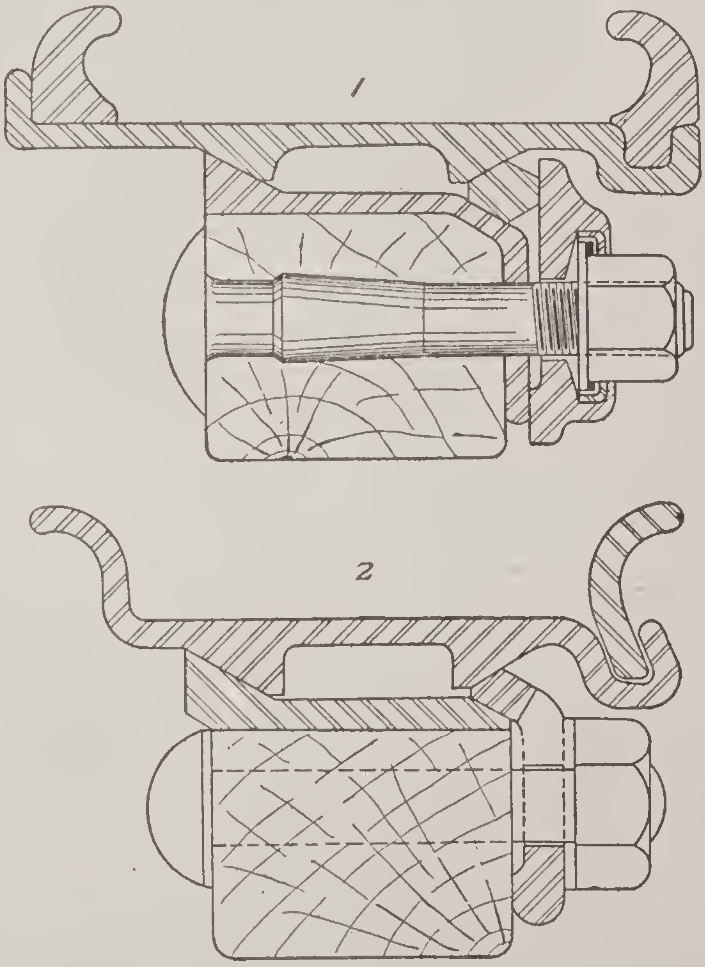


Fig. 540. Sections through Two Popular Forms of Demountable-Detachable Rims

Comparison of Continuous Holding Ring Type with Local Wedge Type. To return to demountable-detachable rims, these may and do include a number of those quick-detachable forms previously shown and described. In Fig. 540, a pair of typical forms is shown, that at *1* being fitted for a clincher tire, while that at *2* is for a straight side. Looking at the detachable part of the rim, *1* will be recognized as that previously shown at *3*, Fig. 521, where it was described as a universal rim, the inversion of the two rings converting it from a clincher to a straight side, or *vice versa.* Similarly, *2* will be recognized as the form of detachable shown at *3* in Fig. 524.

Here, however, both are fitted to be used as demountables, this being accomplished by the formation on the under side of the band of a pair of wedge-shaped projections. The felloe band is so made and applied that it forms one surface to contact with one of these wedges, while the other is formed variously. At *1,* a separate ring is used with the flat outside clips to hold this against both felloe band and rim, while at *2* the wedges or clips have an extension which presses against the outer wedge on the rim. This latter distinction divides these two into the two classes mentioned previously — one into the continuous holding ring class, the other into the local wedge type.

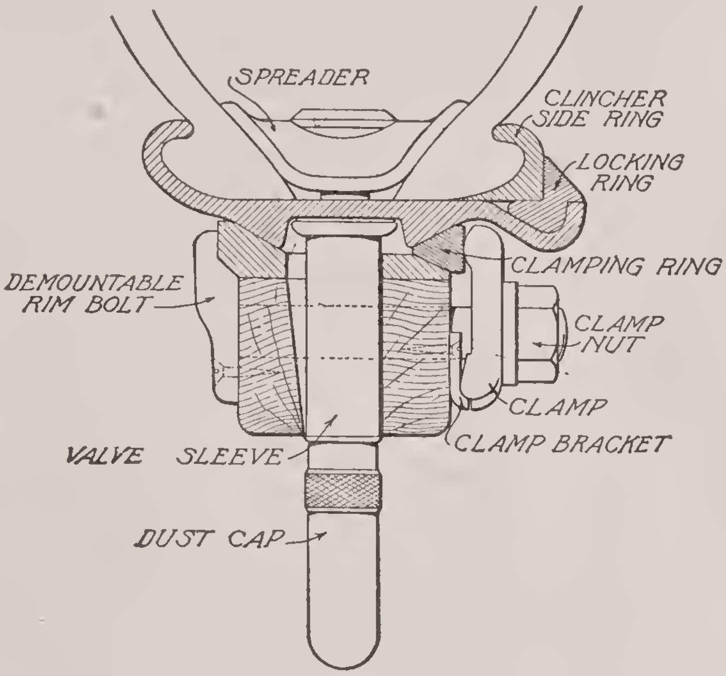


Fig. 541. Section of Tire and Rim of Firestone Demountable Tire

These forms are shown to illustrate this point and also because, despite this difference, they have practically similar felloe bands. This felloe band—that is, of the form shown in *2*—has been recommended as a standard for all demountable-detachable rims. Another and different example of the clamping-ring demountable-detachable type is shown in Fig. 541, this being the Firestone rim. Here, it will be noted, is the felloe band just mentioned, while the detachable-rim portion is that previously shown at *1* in Fig. 523 as having the Z-shaped locking ring and being adapted to clincher tires only. The rim band is made with the two wedge-shaped projections on its underside.

Perlman Rim Patents. Late in the summer of 1915, considerable consternation was caused among tire and rim manufacturers when it became known that the Perlman rim patent had been adjudged basic by the courts, and that, on the strength of this decision, an injunction had been issued against the Standard Welding Company, of Cleveland, Ohio, some few of whose rims have been previously described. Perlman's original patent was applied for on June 29, 1906, and, in addition to this record, the fact was established that the owner had a Welch car which had traveled over 150,000 miles and on which were a set of the original rims. The case dragged through the courts and was discontinued some seven or eight years ago. Perlman persisted, however, although he had to revise and alter his application many times; the basic patents were finally allowed, and issued to him in February, 1913. This means, of course, that the patent will not expire until the year 1930.

Perlman's locking elements and the principle involved are shown in Fig. 542, which is a section through the rim and felloe. In Perlman's suit, it was claimed that the wedge end of the bolt which was covered in his patent, included all wedge-operating rims, whether actuated from the center, as in Fig. 542, or from the side. This contention was supported by the court, and negotiations are now in process between Perlman and many manufacturers of the so-called local wedge type of rim. As this would appear to cover all the rims shown and described in Figs. 525 to 541, inclusive, the influence of this decision upon the industry can be imagined. Moreover, the length of time which this basic patent has to run precludes the possibility of delaying action by prolongation of suits, as has been done in similar cases. A notable example of this is the case of the Selden automobile patents, which were fought on one ground or another over a long period of years.

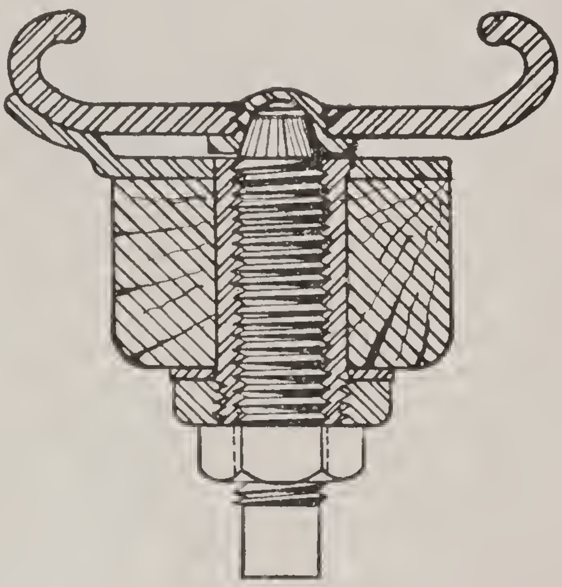


Fig. 542. Section of Perlman Rim, Showing Locking Device

Standard Sizes of Tires and Rims. As might have been noted in going over the above discussion of tires, plain rims, detachable rims, and, finally, demountable rims, all these different constructions require widely differing wheel sizes. It has been proposed to standardize wheels, that is, the outside diameter of the felloe and with it the thickness of felloe bands as well as their shapes or contours, one for each tire cross-section. The proposed reduction of tire sizes to nine standards is as follows: 30- by 3-inch, 30- by 3½-inch, 32- by 3½-inch, 32- by 4-inch, 34- by 4½-inch, 36- by 4½-inch, 38- by 5½-inch and probably 36- by 5-inch, supplying these sizes and these only to manufacturers of cars; additional oversizes are allowed for car users, one for each size above, that is, 31- by 3½-inch for 30- by 3-inch, 31- by 4-inch for 30- by 3½-inch, 33- by 4-inch for 32- by 3½-inch, 33- by 4½-inch for 32- by 4-inch, 35- by 4½-inch for 34- by 4-inch, 35- by 5-inch for 34- by 4½-inch, 37- by 5-inch for 36- by 4½-inch, 39- by 6-inch for 38- by 5½-inch and probably 37- by 5½-inch for the 36- by 5-inch. Rim standardization will follow the adoption of these sizes. In this event, the standardization of demountable rims will come in time.

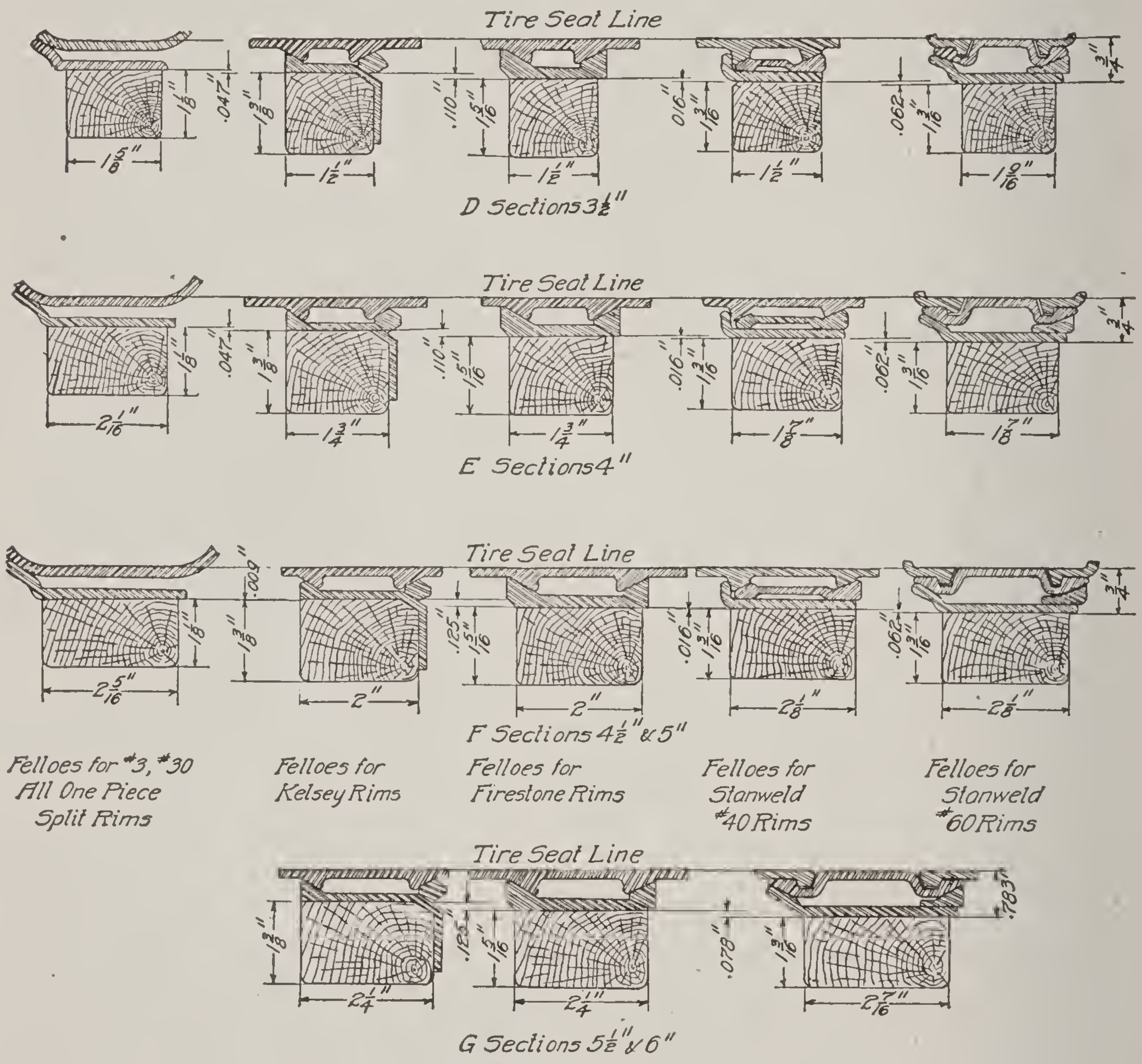


Fig. 543. Typical Felloe, Band, and Rim Sections for Popular Demountable Rims

At the present, there is a wide range of difference, as will be noted in the drawing, Fig. 543, which shows felloes for the most widely used demountable rims, depicting the band and rim in each case. The drawing should be read crosswise, each horizontal line showing the differences to be found in the makes mentioned in that particular tire cross-section size. Thus, the *D* sections show the differences for $3\frac{1}{2}$-inch tires, *E* those for 4-inch tires, *F* those for $4\frac{1}{2}$- and 5-inch tires, and *G* those for $5\frac{1}{2}$- and 6-inch tires, rims for which are not produced by all makers.

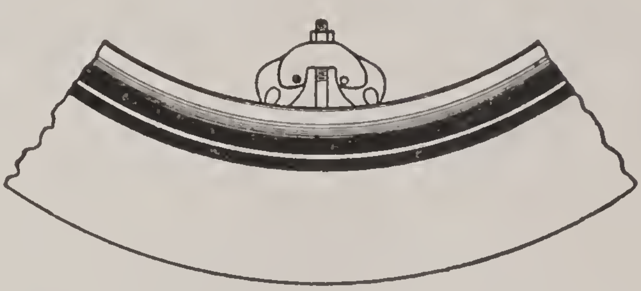


Fig. 544. Operating Device on the Ashley-Moyer Double Q.D. Rim for Wire Wheels

Other Removable Forms. Outside of the regular range of wood wheels and the standard tires for them, any different wheel calls for a different treatment. As has already been mentioned under the subject of Wire Wheels, few of these have anything but a solid one-piece clincher rim; first, because the wheel itself is removable, thus making it as easy to change wheels as to change rims in the ordinary case; and second, to save weight and complication.

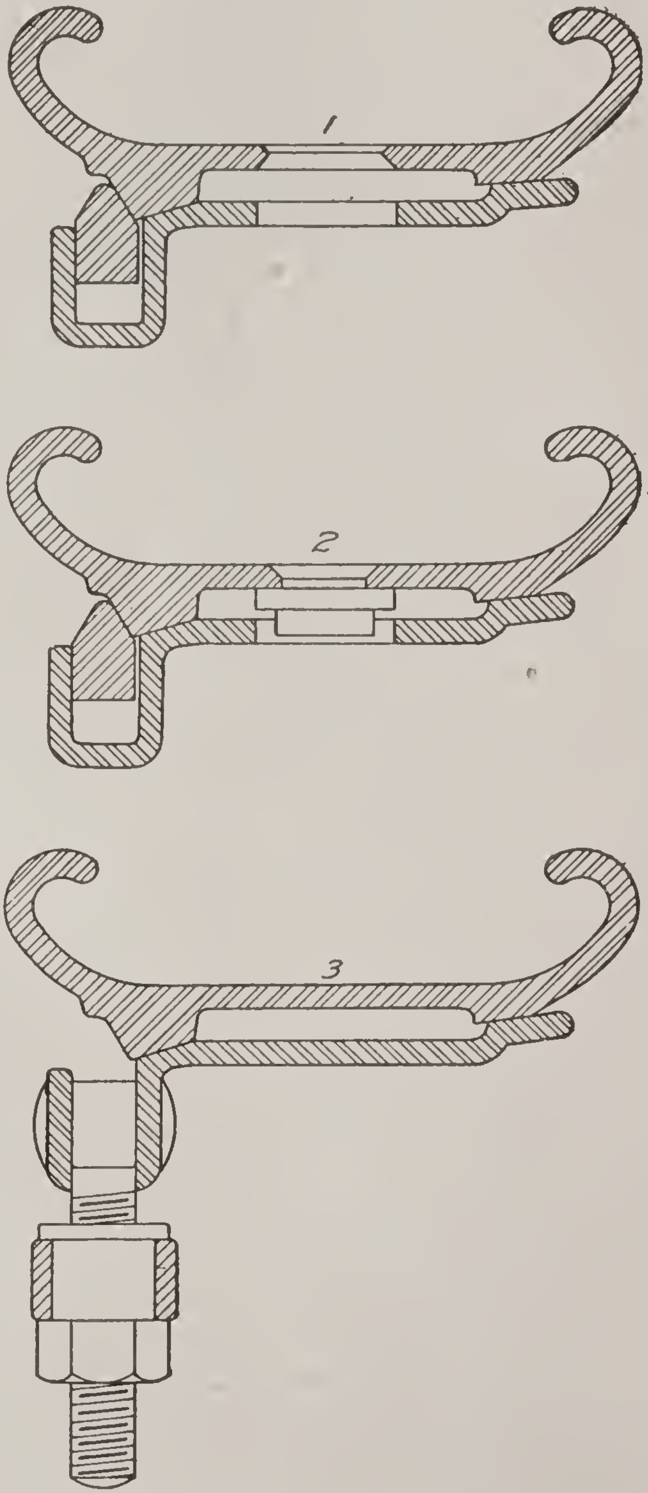


Fig. 545. Section through Rim and Band of G-R-C Rim, Showing Wedging Band and Its Operation

Demountable for Wire Wheels. However, demountable forms have been produced for wire wheels, one being shown in Figs. 544 and 545. This is the G-R-C double Q.D. rim as the makers prefer to call it, in action a demountable-detachable form, the clincher rim being of the straight split type, in fact, a Stanweld No. 20. This is made with a double wedging surface on the outside and a single one on the inside. The latter contacts with another on the false rim to which the wire spokes are attached, as does also the inner wedging surface on the outer wedge. The outer wedging surface is made so as to come just above a fairly deep slot in the false rim. In this is placed a ring with a double wedge-shaped upper edge and a square lower edge. This ring is split at one point and locked in the highest position at the point diametrically opposite.

At the split point, a pair of bent-arm levers, Fig. 544, are connected to the two ends. Attached to a middle point of each of these is one end of an inverted U-shaped member, the center and upper part of which form a bearing for a locking stud, which is attached to one end of the ring. Above this is placed a nut. As will be noted, this forms a toggle motion, the action of which is to expand the whole ring when the nut is screwed down and to contract it when the nut is screwed up.

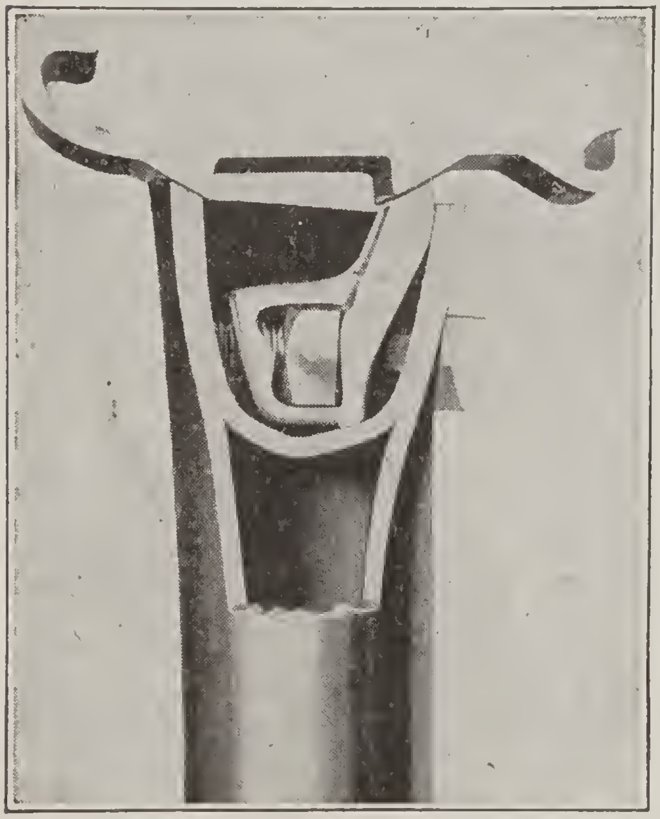


Fig. 546. Construction of Parker Hydraulic Steel Wheel Spokes, and Operation of Locking Device for Rims

This is the precise action used, the single ring forming the whole locking means, and being actuated by the toggle mechanism through the medium of screwing the nut up or down. While at its best on wire wheels because of its simplicity, this rim is, of course, applicable to wood wheels. At present, its makers are specializing on the wire-wheel forms.

Parker Rim-Locking Device. Another rim-locking device which does not come under any of the standard divisions, being devised for use on the Parker hydraulic wheel, previously shown in Fig. 502, is the Parker modification of the former Healy rim. As shown in Fig. 546, which shows the end of a steel spoke in section, this is made with a cup at the upper and inner end, while at the outer is a loose clip, through which passes a bolt with a head on the outside. Tightening the bolt by means of the external head draws the clip up the incline at the bottom of the cup, against the wedge on the underside of the rim, the amount of pressure exerted depending solely upon that applied to the bolt head. As the two wedge shapes oppose each other, this holds the rim as firmly as is possible. It will be noted that this construction does away altogether with the use of felloe bands or false rims used on other forms of rims or wheels, thus saving much weight. Moreover, a great part of the weight is saved at the outside, where the flywheel effect of rapid rotation is thus lessened. Moreover, the absence of additional metal here would give the tire more chance to radiate its heat, and thus would preserve it better. This construction, considering its many advantages, should have a wide use.

Similarly, with all demountable rims, the tendency is toward wider use, with which comes lower cost, as well as a better understanding of their use, abuse, attachment, and detachment. With the standardization of tires to a few standard sizes, say 9 instead of 54, it will be only a few years before all kinds of rims, including demountables, will be standardized, at which time the latter will come into universal use.

TIRE CONSTRUCTION

Composition and Manufacture. Tires consist of two parts, the tube and the shoe, or casing. The former is a plain ring of circular cross-section, made of pure rubber, containing an air valve, and is intended only to hold the air. The shoe, or casing, on the other hand, provides the wearing surface, protects the air container within from all road and other injuries, and constitutes or incorporates the method of fastening itself to the wheel. In its construction are included fabric—preferably cotton—some pure rubber, and much rubber composition, the whole being baked into a complete unit by heat in the presence of sulphur, which acts somewhat as a flux for rubber.

Considering a typical tire, there enters into its make-up, starting from the inside, six or seven strips of frictional fabric, that is, thin sheets of pure gum rubber rolled into intimate contact with each side of the cotton, making it really a rubber-coated material. Next, there is the so-called padding, which is more or less pure rubber, has a maximum thickness at the center of the tread, and tapers off to nothing at the sides, but usually carrying down to the beading.

Above this there is placed a breaker strip, consisting of two or three layers of frictioned fabric impregnated in a rubber composition. This, too, is thickest at the center and tapers off to the sides, but ends at the edge of the tread. Finally, there is the surface covering, called by rubber men the tread; this contains very little pure rubber, being thickest at the center and extending with gradually decreased thickness almost down to the bead.

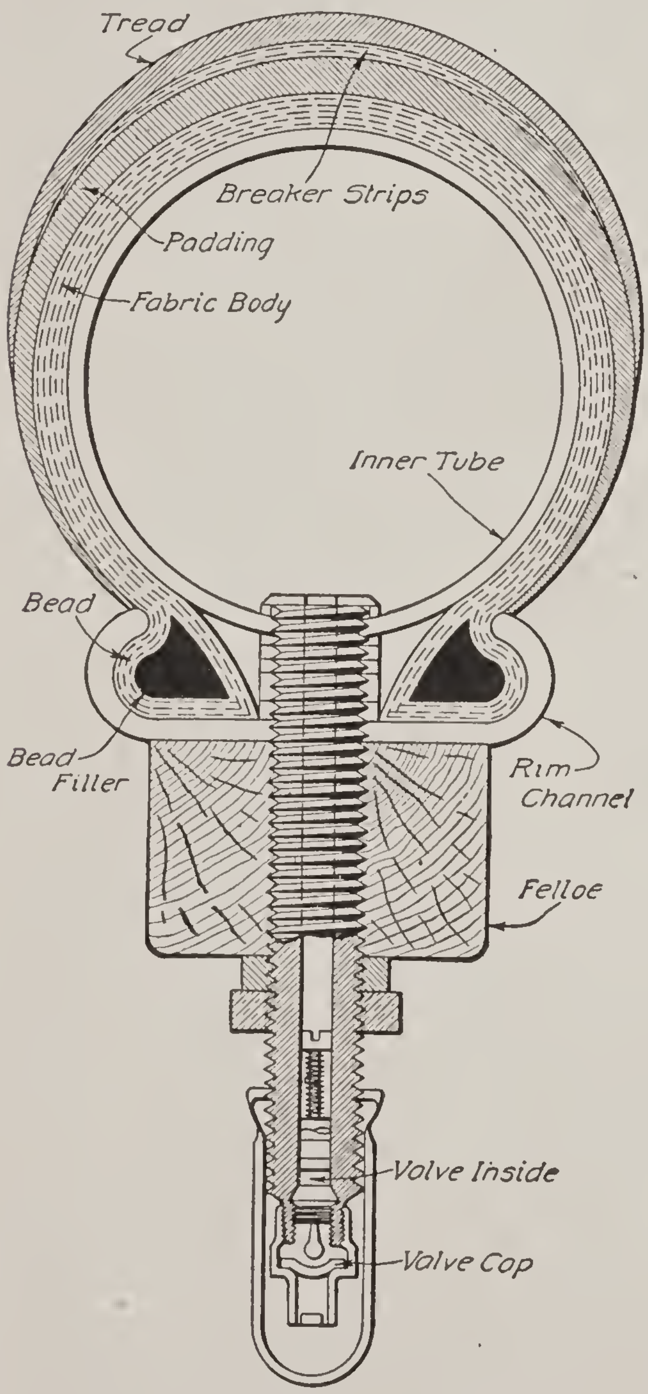


Fig. 547. Section through Assembled Tire and Tube, Showing Construction and Parts of the Tire and Tire Valve

The last two of this series of layers constitute the real wearing surface of the tire, and when the surface is so worn that the breaker strip may be seen, it is time to have the tire retreaded. When the wear has gone through this, if the padding be fairly complete, retreading will still save the tire, but if wear has gone clear down through that so as to expose the fabric, the show must be run to a finish and then discarded.

All this construction can be noted in Fig. 547, which shows a section through a tire, with the inner tube in place, the section being taken so as to pass through the center of the tire valve. This should be borne in mind when examining this figure, for the location of the inner tube inside the tire, as previously described, is likely to be misleading.

Bead. In the reference to tire construction, no mention has been made of the bead. This is a highly important part of the tire, for it is the part which holds it in place on the wheel. It is made of a fairly hard rubber composition, the fabric being carried down on the sides so as to cover it. In a cross-section, it has a shape very close to an equilateral triangle resting on its base; around the wheel it is curved to fit the rim. The method of attaching the tire has a considerable influence on bead construction, since, in the clincher type of tire, in which the shoe must be stretched on over the rim, the bead must be extensible in order to insure easy mounting. In the quick-detachable and straight-side forms of tire there is no need for this stretching, so the bead can be made of stiff and rigid material as well as cut down somewhat in size.

The straight-side or Dunlop type of tire is seldom made with much of any bead, the layers of fabric being carried straight down. A more modern form of tire has a pair of woven-wire cables incorporated in the bead to make it stiffer and stronger, and this is said to have been very successful. As has been pointed out previously, this could be done only with the quick-detachable form, not with the clincher type.

In both the clincher and the quick-detachable forms, the bead holds the tire to the wheel by means of parts of the rim, which bear on it from above, as well as sidewise, the internal pressure when the tire is inflated pressing it against these parts very firmly.

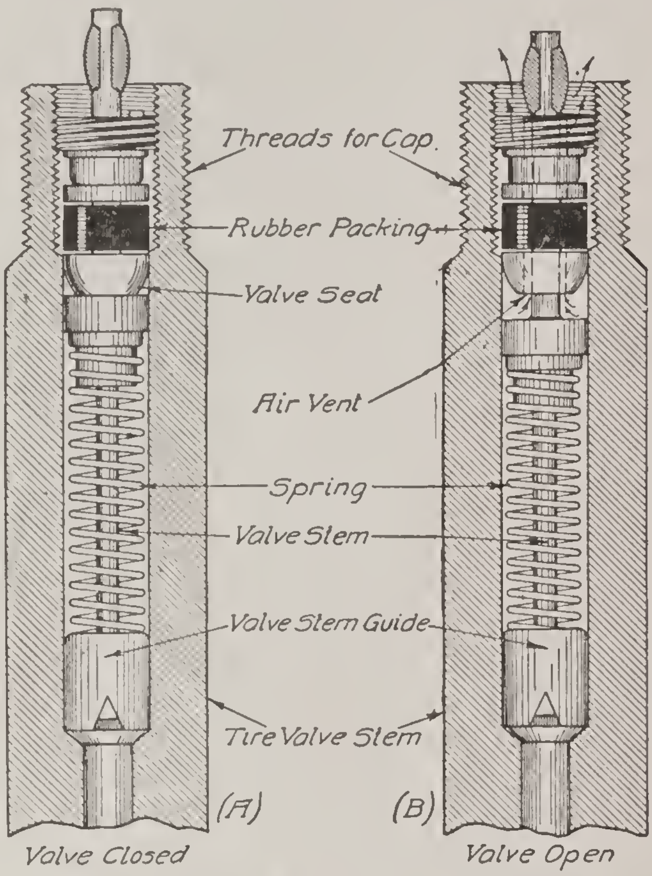


Fig. 548. Views of Tire Valve, Showing Closed and Open Positions

In both the clincher and the quick-detachable forms, the bead holds the tire to the wheel by means of parts of the rim, which bear on it from above, as well as sidewise, the internal pressure when the tire is inflated pressing it against these parts very firmly.

Tire Valves. In Fig. 547 there is shown a section through the tire valve but on a small scale. As this is a very important part and little understood, a larger view is shown in Fig. 548. This is in two parts, *A* at the left showing the valve closed, and *B* at the right indicating the position of the various parts when the valve is open. Note that the lower part of the valve is hollow, so that air inside of the tire has access to the valve seat. Note that the valve is held down on this by the threaded portion above it. This valve seat forms a slight taper which rests against an equally slight taper inside of the valve stem.

One condition of the tire valve holding air pressure is that the two valve seats be clean and smooth and free from scratches or cuts and foreign matter. Now it will be observed that the valve-seat portion of the valve has a hole through the center, in which the stem is a loose fit. This large hole passes all the way up through the threaded portion. The stem has a projection below the valve seat, which normally is held up against the bottom of the seat by the spring, this being strong enough to hold it up so tightly that no air can pass between the two. There are other conditions for valve tightness. The spring must be strong enough to hold these parts together; and the surfaces must be clean and true so that when held together, no air can get through.

Action of Valve. The action of the valve is this: When air is pumped in, it passes down around the central stem until it meets the projection, which it forces down against the pressure of the spring and, when there is air inside, against the pressure of the internal air. As soon as this is pressed down, the air passes in, and if the external pressure is stopped, as at the end of a stroke of the pump, the spring and the internal pressure push the projection back into place, and no air can escape. On the next pressure stroke of the pump, this is repeated, the whole process continuing until the tire is filled.

Leaky Valves. It will be noted that with a good clean spring, projection, and valve seat, the pressure of the air itself holds the valve tight. Thus, when a valve leaks, it is a sure sign that some part or parts of it are not in good condition. If the valve is not screwed down far enough, air can leak out around the valve seat, so that leakage may be remedied by screwing the whole valve farther down into the stem. If the valve stem is too tight a fit in the central hole, it may stick in a position which allows air to pass. This can be remedied by a drop of oil placed on the stem and allowed to run down it. But not more than one drop should be used as oil is the greatest enemy of rubber, and the tube with which the valve communicates is nearly pure rubber.

If the spring is too weak to hold the projection against the bottom of the valve seat, the valve will leak. This can be remedied by taking out and cleaning the spring, also stretching it as much as possible. In general, however, the best plan of action with a troublesome tire valve is to screw it out and put in a new one. These can be bought for fifty cents a dozen, and every motorist should carry a dozen in a sealed envelope, also a combination valve tool. When trouble arises with the valve, or a tire leaks down flat with no apparent cause, screw out the valve with the tool, screw in a new one, make sure it is down tight, and pump up again. The few cents it will cost to throw away a valve, even if it should happen to be good, will be more then compensated for by the time saved. Another point is that the whole valve assembly is so very small that it is difficult to handle.

Washing tires often is a good practice, since water does them no harm, while all road and car oils and greases will be cleaned off, nearly all of these being injurious. Frequent washing will also serve to call the attention of the owner to minor defects while they are still small enough to be easily repaired, and thus they are prevented from spreading. When not in use, tires should be wrapped, so as to be covered from the light, and put away in a dry room in which the temperature is fairly constant the year round. They will not stand much sunlight, nor many changes in temperature. Cold hardens the tires and causes the rubber to crack. Heat has a somewhat similar effect and also draws out its life and spring.

In general, of all things to be cared for and repaired promptly, no one thing is of more importance than the tires. If this rule is kept in mind, better satisfaction in the use of the car will result. So, too, with other repair work; if tools and appliances are made available and repairs made as soon as needed, the car will be better understood and give more satisfaction than if the opposite course be pursued. A few months of use of a car will do more to emphasize this than any amount of talk. Keep your car in good condition and you will reap the benefits of the little work you do upon it.

TIRE REPAIRS

Repair Equipment

Vulcanization of Tires for Repair Man. In practically all of the following material the point of view is that of the professional repair man, or of the garage man about to take up tire repairs, as distinguished from that of the average owner or amateur repairer. The lesser tire injuries and their repairs are handled from an amateur standpoint in another part of this work.

Vulcanization, to the unitiated, sounds very mysterious, but it really is nothing more or less than cooking, or curing, raw gum rubber. In the processes of manufacture a tire is cooked, or cured, all the component parts supposedly being united into one complete whole. A tire is repaired preferably with raw gum or fabric prepared with raw gum, and, in order to unite this to the tire, vulcanization or curing is necessary. The curing, in addition to uniting the parts

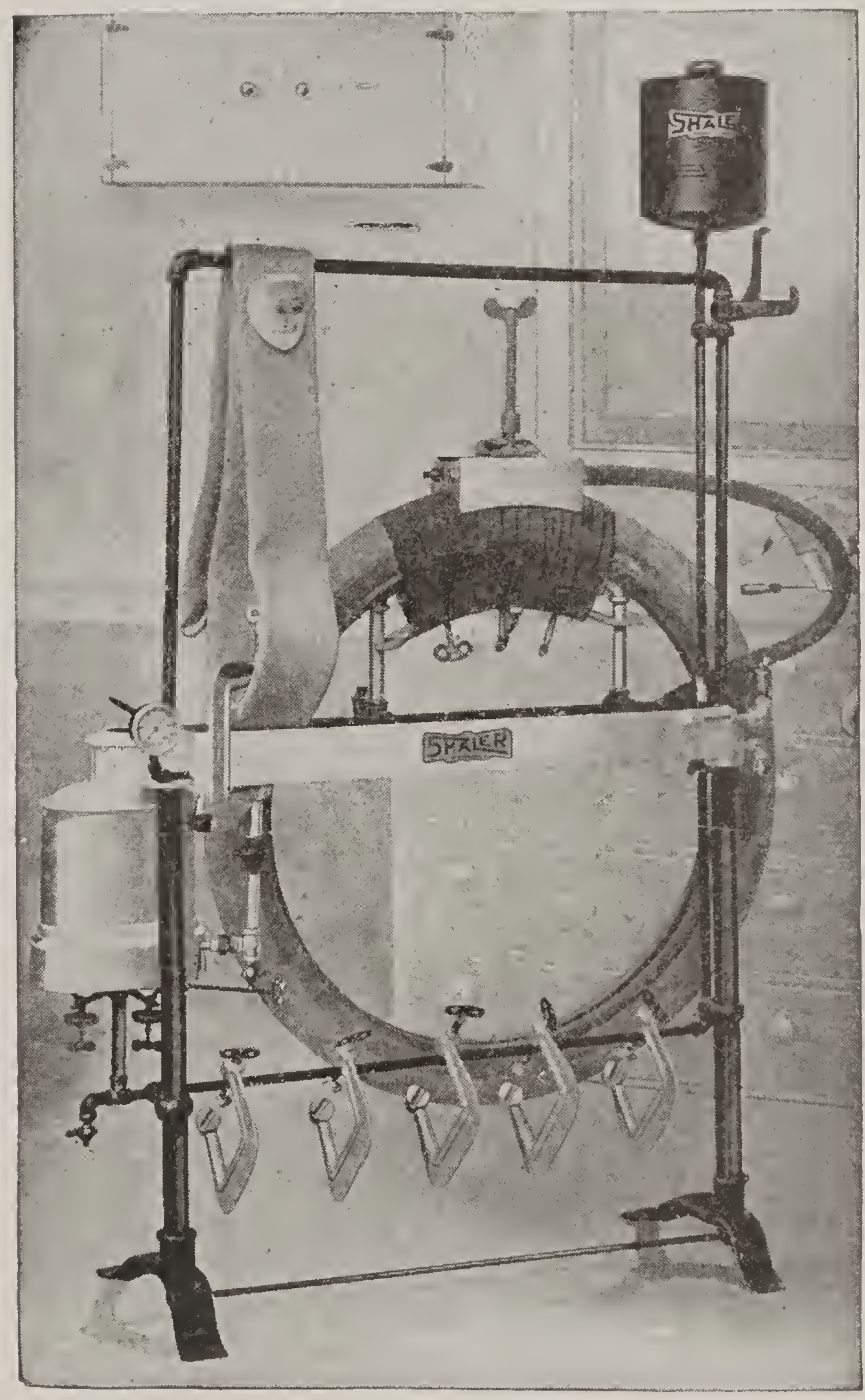


Fig. 549. Small Vulcanizing Outfit for Single Casing of Six Inner Tubes
Courtesy of C. A. Shaler Company, Waupun, Wisconsin

properly, gives the proper strength, or wear-resisting qualities, which raw rubber lacks.

Types of Vulcanizing Outfits. *Shaler Vulcanizer.* This curing, or cooking, is done by the application of heat, in a variety of ways. Generally, very small individual vulcanizers have a gasoline or alcohol cavity, holding just enough of the liquid so that when lighted and burned the correct temperature will be reached and held for the correct length of time. The larger units are operated by steam or electricity; the latter is preferred for its convenience, but the former is used by the majority of repair men. The source of heat is immaterial so long as the correct temperature is reached and maintained for the right lengh of time. Too hot a vulcanizer will burn the rubber, while too low a temperature will not give a complete cure.

For the average small repair man, the outfit shown in Fig. 549 will do very nicely, at least to start with. This will handle a single casing or six tubes, or in a press of work, both simultaneously. This outfit is operated by gasoline, contained in the tank shown above at the right, but the same outfit can be had with pipe arrangements for connecting to a steam main, or for electric heating. In the case of either gasoline or steam, there is an automatic temperature controlling device which is a feature of the Shaler apparatus. As shown, casings are repaired by what is known as the "wrapped tread method", the repair being heated from both inside and outside at once, the outside being wrapped. Tubes are handled on the flat plate, shown in the middle of the framework, the size of which is 4½ by 30 inches, this being sufficient, so the makers say, to handle six tubes at once.

Haywood Vulcanizer. For larger work, a machine something like the Haywood Master, shown in Fig. 550, is excellent. This is a self-contained unit, carrying its own gasoline tank, steam generator, and other parts. It handles four casings at once, while the tube plate *G*, 5 by 18 inches, is large enough for from three to four tubes, according to the allowance per tube made in the Shaler outfit. The separate vulcanizers are not designed for the same part of a casing, a side wall and bead vulcanizer being shown at *D*, a sectional vulcanizer for large sizes at *E*, a sectional vulcanizer for small and medium sizes at *F*, and a side wall and bead vulcanizer for both clincher and straight-side tires at *H*. The gasoline tank is marked *C*, with vertical pipe in which is the gasoline cut-off valve *K*. This leads down to the gasoline burner *M*, where the gasoline in burning vaporizes the water into steam. The water gage *L*, which indicates the amount of water available, is placed on the side of the steam generator *A*. Above this steam generator is the steam dome at *B*, from which the steam pipes lead to the various molds. The returns, or rather drips, will be noted, also the steam gage (not marked) and the cut-off valve in the supply pipe to the sectional molds. In addition to the molds shown and a full supply of parts and tools, sectional vulcanizers for 2½- and 3-inch tires, relining mold for 2½-, 3-,

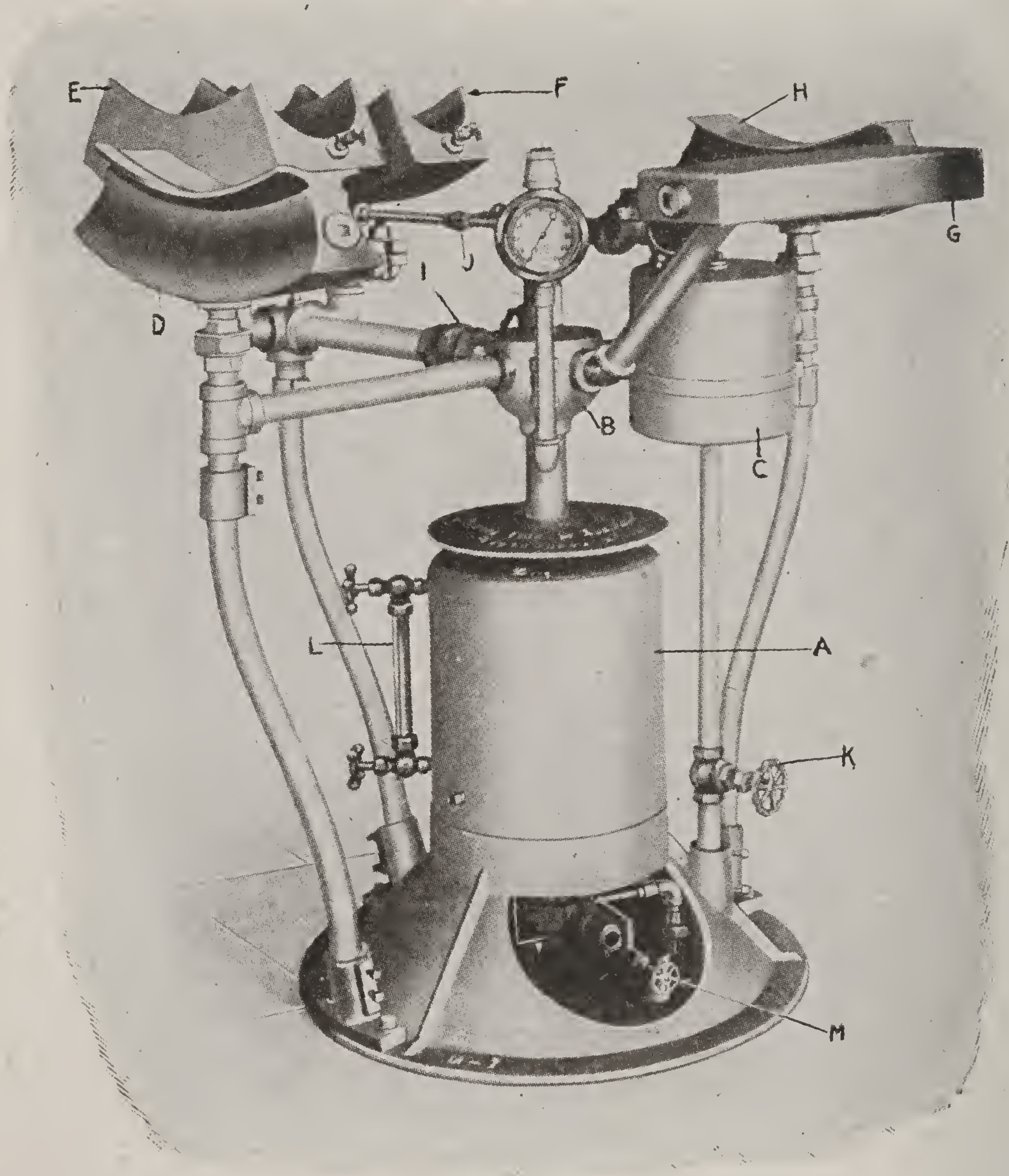


Fig. 550. Master Vulcanizer with Self-Contained Steam Generator
Courtesy of Haywood Tire and Equipment Company, Indianapolis, Indiana

and $3\frac{1}{2}$-inch tires, and relining mold for 4-, $4\frac{1}{2}$-, 5-. and $5\frac{1}{2}$-inch casings come with the device.

This outfit with the extra molds, described but not shown, gives a very complete equipment for the small shop doing average repairing. In fact, when a shop outgrows this type of equipment, it must specialize in tire work and purchase special equipment.

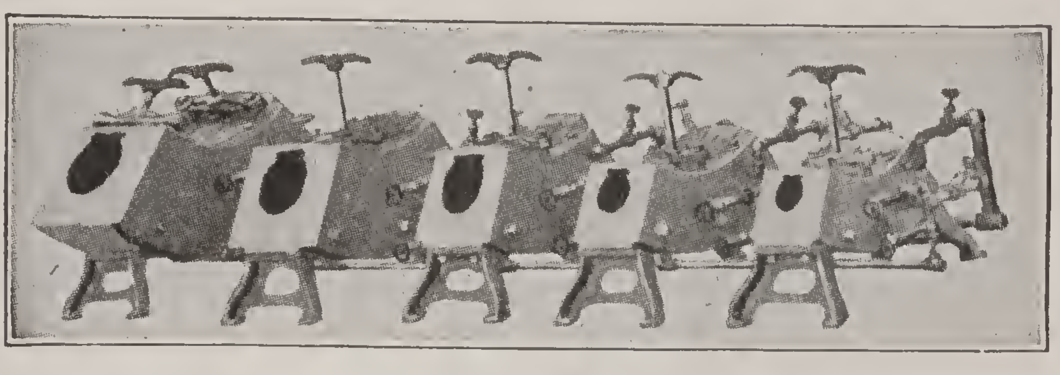


Fig. 551. Battery of Vulcanizing Mold for Various Sizes of Tires

Separate Casing Molds for Patch Work. In the way of separate molds for casings, an excellent example of the localized heat type is shown in Fig. 551. By this is meant the form designed to vulcanize a small short section of a tire. The illustration shows five sections capable of handling, respectively, $2\frac{1}{4}$-, to 3-inch (motorcycle), $2\frac{1}{2}$- to 3-inch (small car), $3\frac{1}{2}$- to 4-inch, $4\frac{1}{2}$- to 5-inch, and $5\frac{1}{2}$- to 6-inch tires, thus covering the entire range. These molds have a special arrangement in that the heating portion is divided into three sections, into each of which steam can be admitted separately. This allows the use of one, two, or all the sections, according to the nature of the repair.

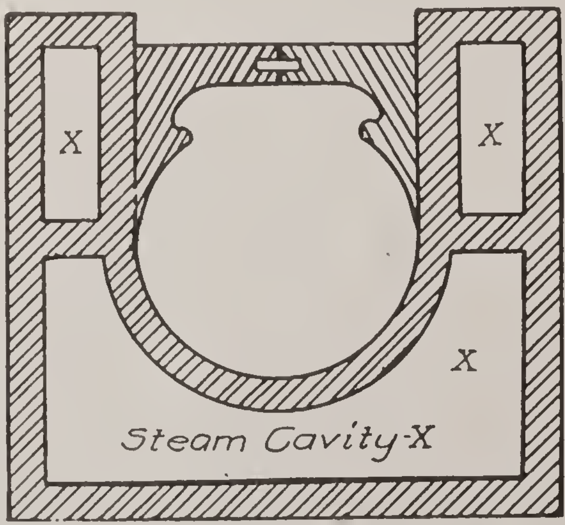


Fig. 552. Section of Vulcanizer, Showing Steam Cavities

In Fig. 552 is shown how it is possible, with this apparatus, to vulcanize the tread portion only by admitting steam solely to the larger bottom steam chamber around the tread, similarly, with the right-hand bead or side wall or the left-hand bead or side wall. When a complete section is to be vulcanized, all sections are opened. The importance of this will be realized in a simple consideration of the fact that the tire itself has already been vulcanized and further heat is not only not good for it, but is distinctly bad, as it deteriorates the rubber. Where the heat is needed, however, is not the raw rubber which has just been added at the repair point, this being practically useless until it has been cured.

Vulcanizing Kettles. *Horizontal Type.* When it comes to vulcanizing an entire tire, as, for instance, when a new tread has been put on, or other very large repair, what is known in the trade as a "kettle" is needed. This is simply a heavy steel tank, large enough to take one or more entire tires, steam being admitted to its interior to vulcanize them. The kettle shown in Fig. 553 has a capacity of two casings 36 inches in diameter or smaller. It is of the type in which no bolts or nuts are used for fastening the cover, this being held fast by the projecting lugs which lock under other projections on the top of the kettle when the cover is turned. A special rubber packing ring also is used, Fig. 554, effectually sealing the kettle against steam leakage. This kettle resembles a doughnut in shape, the tires lying within the circular cavity.

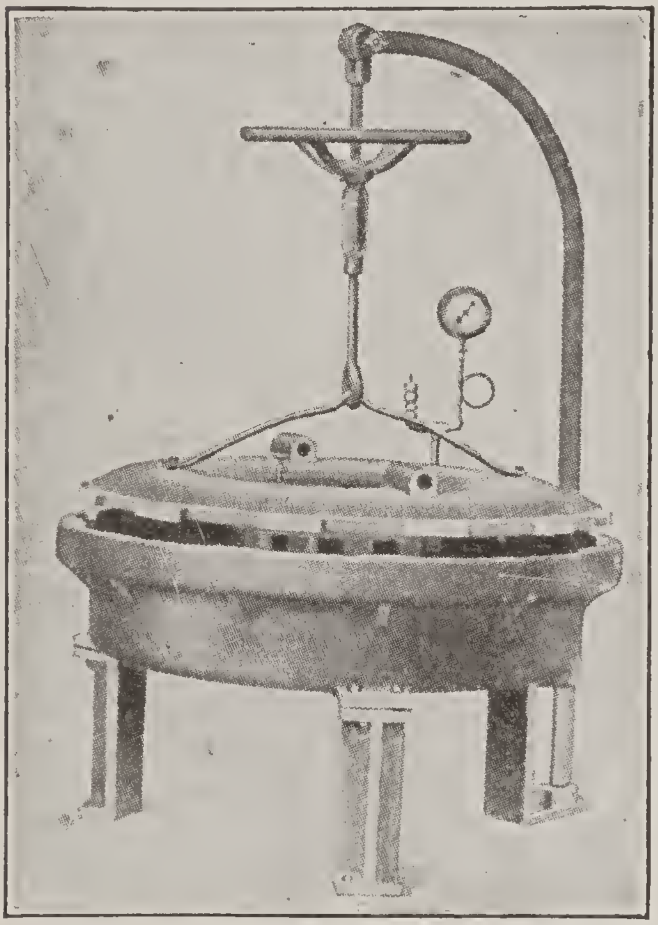


Fig. 553. Vulcanizing Kettle, Horizontal Type

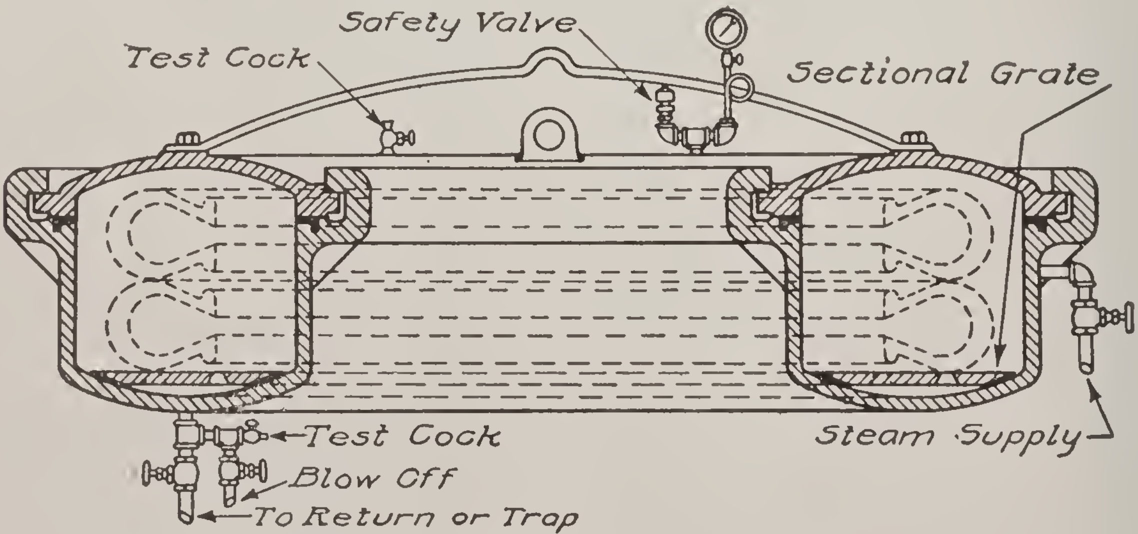


Fig. 554. Section of Horizontal Vulcanizing Kettle

Large Vertical Type. When the work goes beyond the capacity of size and type of tank or kettle shown in Fig. 553, which will handle two casings at a time, and at least two, perhaps four, kettles full an hour, that is, from 40 to 75 casings a day, it becomes necessary to use a larger type of kettle, made in vertical types only. These consist simply of large round steel shells with hinged heads, into which the tires can be rolled and piled, after which steam is admitted to the whole interior. They vary in size from 36 inches inside diameter by 24 inches in length to 48 inches diameter by 40 inches in length.

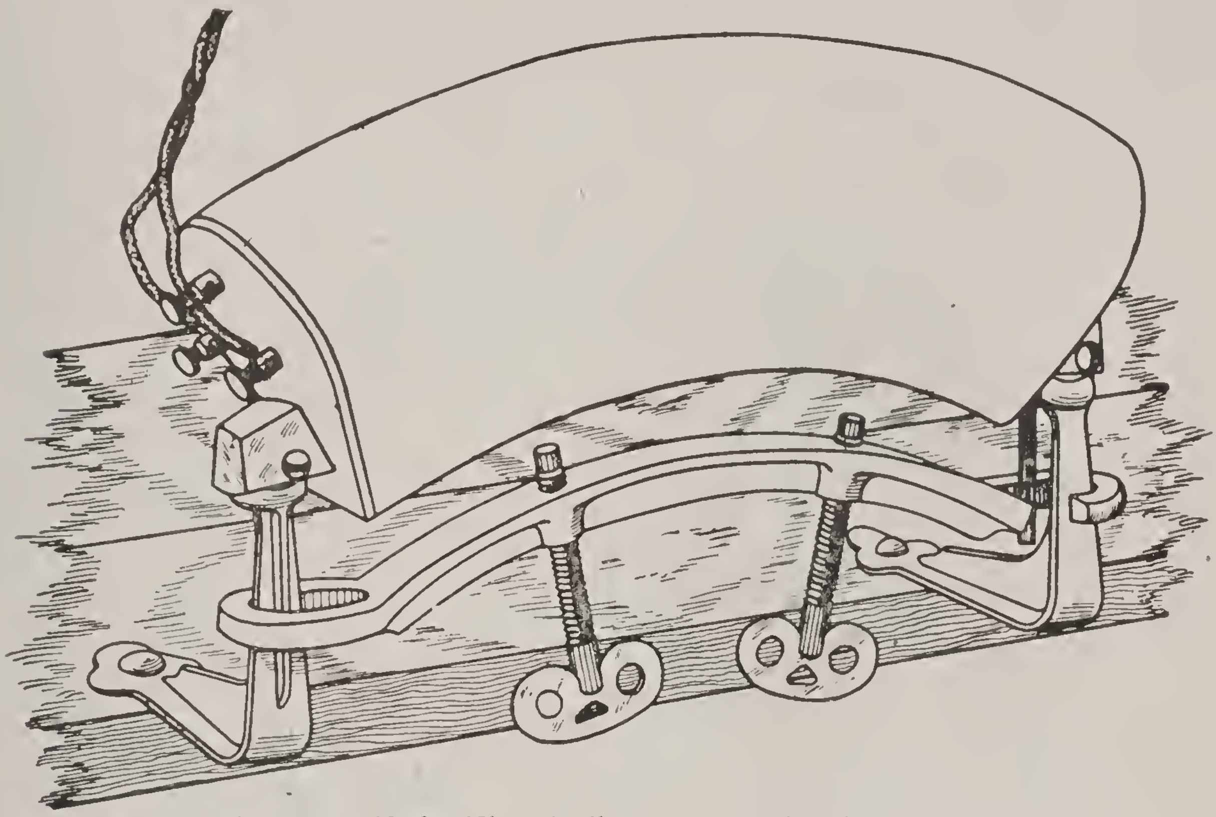


Fig. 555. Shaler Electrically Heated Inside Casing Form

Inside Casing Forms. Another requisite of the tire specialist is an inside casing form, such as is shown in Fig. 555, or something similar. Many tire repairs are inside work, and even on those which are external, it is important to have an inside form against which the tire can be pressed and firmly held while vulcanizing. This particular form is heated by electricity, the wires being shown at the left; it is 14 inches long and has an external shape to fit the inside of all casings.

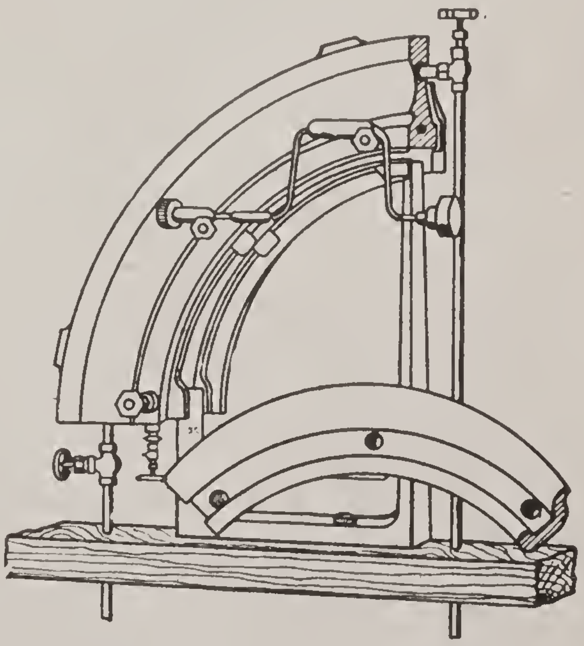


Fig. 556. Side-Wall Vulcanizer

Side-Wall Vulcanizer. A shop doing a great deal of work can use to good advantage the side-wall vulcanizer shown in Fig. 556.

It has a single central member through which the steam passes, and also has bolted-on side plates, the insides of which are formed to suit either clincher or straight-side tires. In the figure, the side plates are not both in place, one being shown on the work table below. The brace shown is used to remove the clamping nuts quickly and easily. This form is very useful on all side-wall or bead operations. It applies greater pressure along these parts of the tire than an air bag; it exactly fits the tire, and the size and shape make it possible to vulcanize a 36-inch tire in four settings.

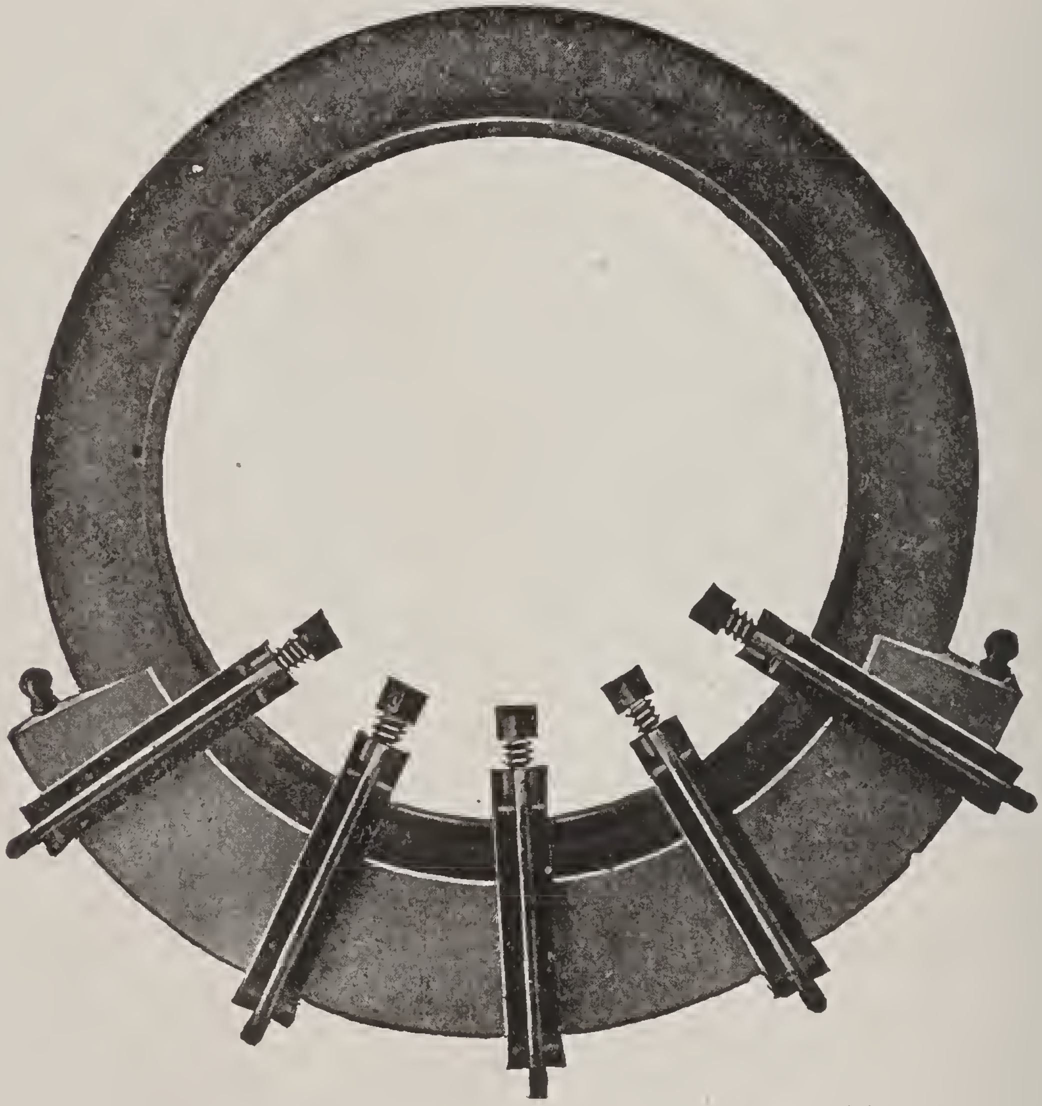


Fig. 557. Retreading Vulcanizer with Tire in Position
Courtesy of Haywood Tire and Equipment Company, Indianapolis, Indiana

Retreading Vulcanizers. Retreading vulcanizers differ from the sectional molds of Figs. 549, 550, and 551 in that the heat is applied at one particular point or, rather, strip along the middle of the top surface of the casing and extending down only as far as the side walls. Such a device, shown in elevation in Fig. 557, and in enlarged sectional detail in Fig. 558, is used solely for retreading or vulcanizing a new tread strip around the tire. The complete unit extends around about one-third of the whole tire surface so that when putting on a complete new tread the mold must be used three times. The section, Fig. 558, is numbered as follows: casing, 2; inner mold, 1; new tread to be vulcanized, 3; vulcanizer proper, 4; clamp, 5; and steam space within which the heating is done, 6.

Layouts of Equipment. There are two ways of installing an outfit somewhat like that just described, namely, by the non-return system and by the gravity-return system.

Non-Return Layout. A typical installation according to the non-return system is shown in Fig. 559. A steam trap must be placed in the system to remove the water and discharge it either into the sewer or into a tank so that it can be used again. In the figure there is shown a tube plate, a three-cavity sectional vulcanizer, two inside molds, and a medium size kettle of the vertical type placed in order from right to left. A pressure-reducing valve is shown which permits the use of a higher pressure in the boiler, thus maintaining an even steady pressure on the vulcanizers regardless of fluctuations at the boiler.

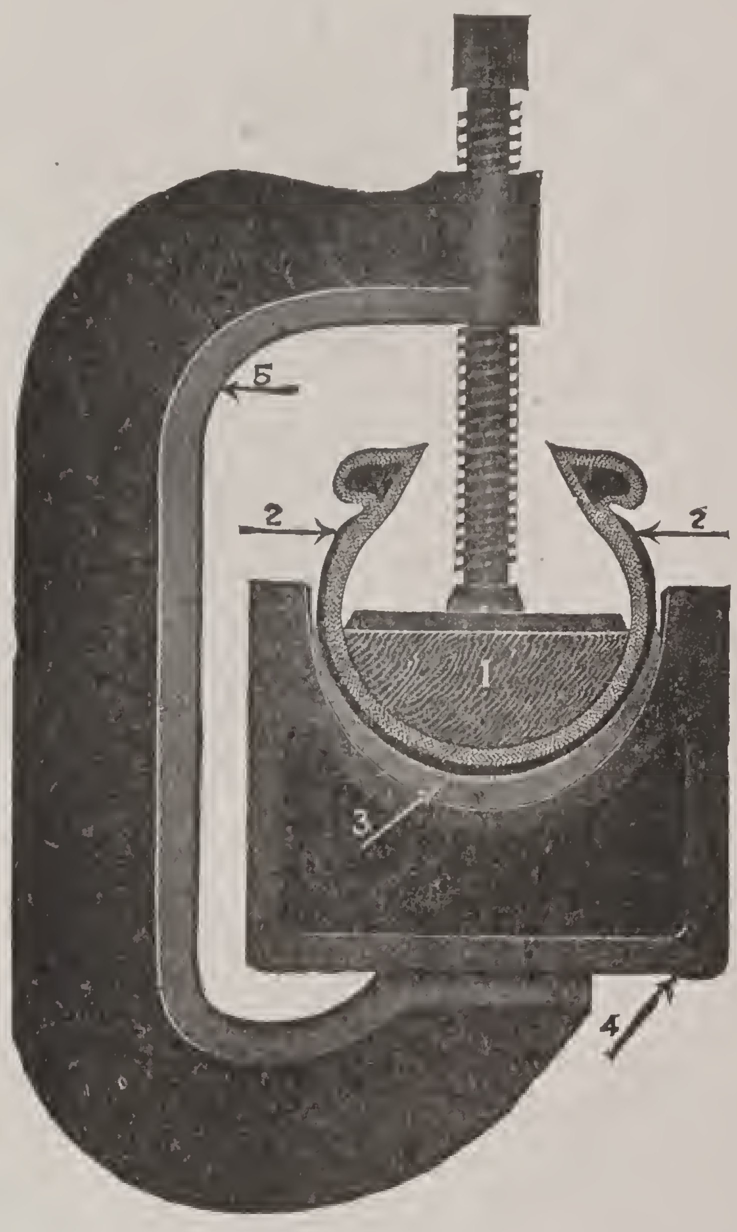


Fig. 558. Section of Retarding Vulcanizer
Courtesy of Haywood Tire and Equipment Company, Indianapolis, Indiana

Gravity-Return Layout. When the coil steam-generator or flash type of boiler is used, the gravity-return system is utilized, this being a method of piping by means of which the condensed steam is returned to the coil heater to be used over again. This makes it necessary to set the apparatus so that the water of condensation will run back to the coil heater, which means that the pieces must be in a series, each successive one being set a little lower down to the boiler. Figs. 560 and 561 show a side view and plan view, respectively, of a small

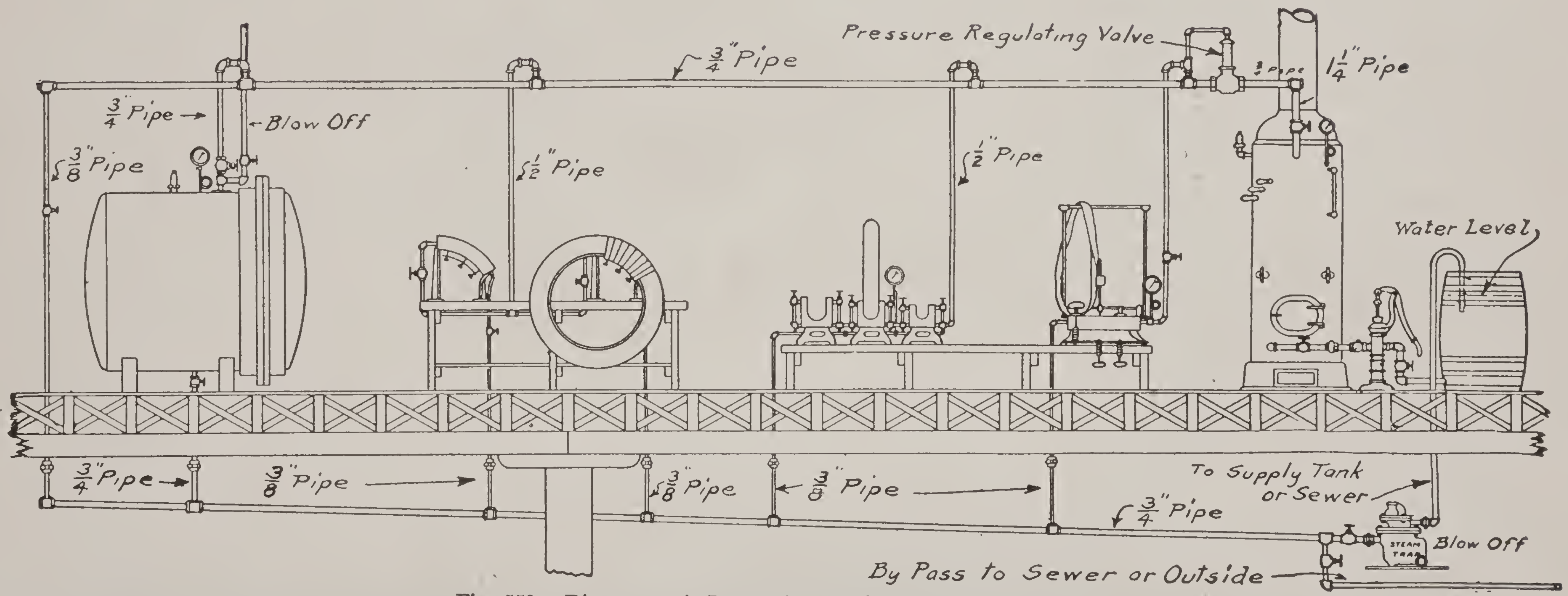


Fig. 559. Diagrammatic Layout for Non-Return Vulcanizing Plant

plant arranged on this plan. The outfit consists of the coil heater, which may be fitted to burn gas or gasoline, two inside molds, a large tube plate, and a three-cavity sectional vulcanizer. The outfit differs from Fig. 559 only in the absence of the kettle; on the other hand, the tube plate in Fig. 560 is larger.

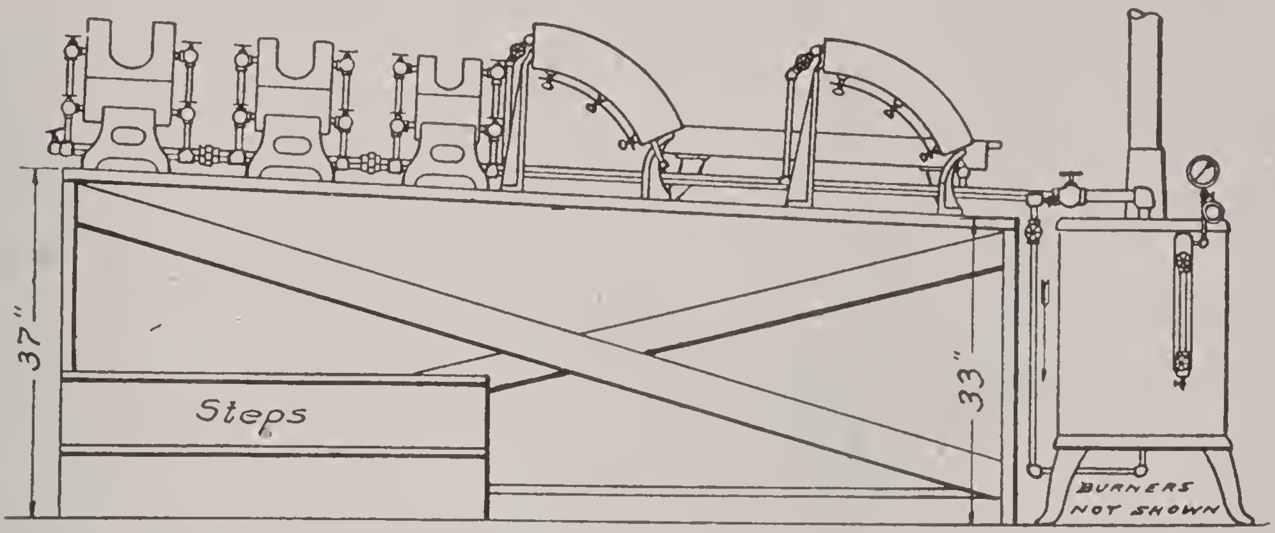


Fig. 560. Elevation of Gravity-Return Vulcanizing Plant

Small Tool Equipment. In addition to these larger units, the well equipped tire repair shop should have a considerable quantity of small tools, among the necessities being those shown in Fig. 562. At *A* is shown a flat hand roller and at *B* a concave roller. *C* shows an awl, or probe, which is used for opening air bubbles and sand blisters. *D* is a smooth stitcher; *F* a rubber knife, of which two sizes are advisable, a large and a small; and *G* a 10-inch pair of shears for trimming inner tube holes, cutting sheet rubber, etc. *H* is a steel wire brush for roughing casings by hand; a preferable form is a rotary steel wire type driven by power at high speed. *I* is a similar

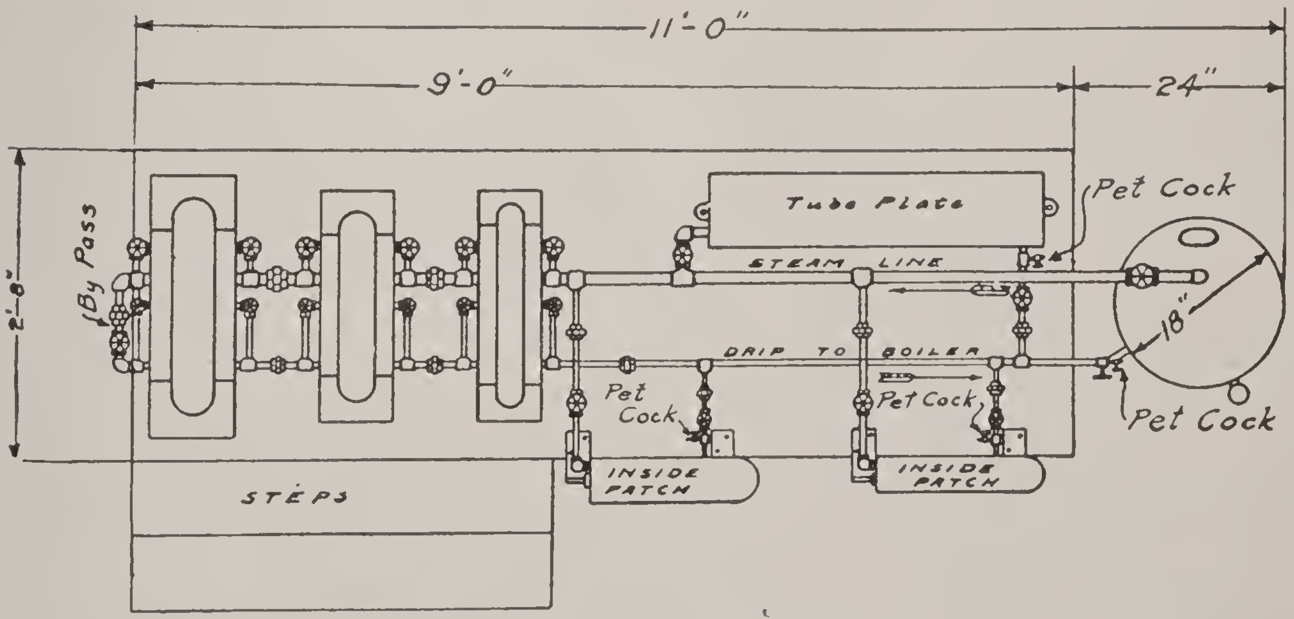


Fig. 561. Plan View of Gravity-Return Vulcanizing Plant

wire brush for roughing tubes; and *J* another brush with longer wires, also for roughing casings; *K* is a tread gage for marking casings to be retreaded; and *L* a fabric knife necessary in stepping down plies of fabric. *M* is a pair of plug pliers for placing patches inside of small tube repairs; *N* is a cement brush for heavy casing cement, another very much smaller and lighter one—preferably of the camel's hair type—being used for tube cement. *O* is a hand scraper and *P* a tread chisel; *Q* performs a somewhat similar function, being a casing scraper for cleaning the inside of a casing preparatory to mending a blowout.

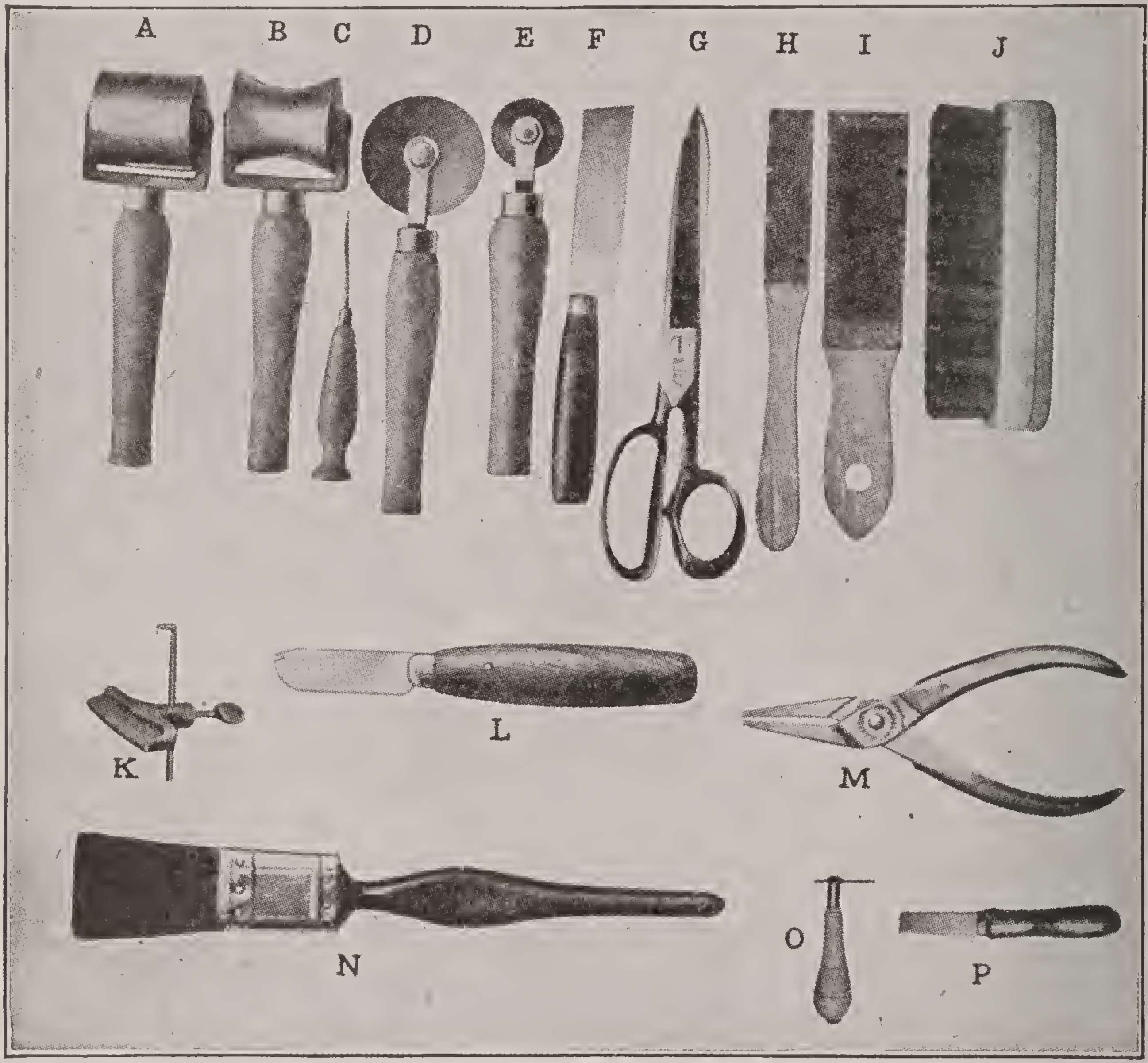


Fig. 562. Collection of Tools Necessary for Vulcanizing Work

In addition to the small tools shown in Fig. 562, it is necessary to have several tube-splicing mandrels; a large number of various sizes and shapes of clamps for all purposes; rules, try-squares and other measuring tools; tweezers for handling small patches, tools for recutting threads on tire valves; tire spreaders, for holding casings open when working inside; a casing mandrel or tire last of cast iron for holding a casing when making repairs; a tread roller for rolling down layers of raw stock evenly and quickly; a considerable amount of binding tape; thermometers; and such motor-driven brushes, scrapers, etc., as the quantity and quality of the work warrant.

Materials. Each repair shop must carry such a supply of tire-repairing material as the nature and quantity of its business demands. Among other things may be mentioned: Tread stock, rebuilding fabric, single-friction fabric, cushion stock, breaker strips, single-cure tube stock, combination stock, cement, quick-cure cement, soapstone, valve bases, valve insides, valve caps, complete valves, vulcanizing acid, various tube sections, tire tape, cementless patches, as well as many other tire accessories to sell. Many good tire-repair shops find a legitimate use for special tire-repairing preparations on the order of Tire-Doh.

Inner Tube Repairs

In general, all tire repairs come under one or more of the following headings; puncture; blowouts; partial rim cut or rim cut all around; and retreading or recovering, and relining.

Simple Patches. Under the heading of punctures are handled all small holes, cuts, pinched tubes, or minor injuries. Generally, these can be repaired by putting on a patch by means of cement, or with cement and acid curing. When well done, this method is effective. This kind of a job seldom comes to the repair man, and, when it does, it is principally because the owner is too lazy to do the work. About the only two cautions necessary are relative to cleanliness and thoroughness. The tube and patch should be thoroughly cleaned. Again the patch should be large, well cemented, and the cement allowed to dry until just sticky enough to adhere properly. Many a simple patch of this kind has been known to last as long as the balance of the tube.

Large Patches. *Cleaning the Hole.* Whenever the hole or cut is large, it is recommended that the repair be given more serious attention and vulcanized. The ragged edges of the rubber should be trimmed smooth with the tube shears or knife, the minimum amount of rubber being cut away. The hole, however, should be made large enough to allow the insertion of an inside patch. Then the tube around the hole should be cleaned thoroughly. This is best done with a cloth wet with gasoline, cleaning not only the outside but the inside around the hole and at the edges. In order to make a good job of this, it should be gone over several times; the larger the hole the more care should be used in cleaning around it.

Preparing the Patch. Having the hole well cleaned and ready, these cleaned parts should be painted with two coats of vulcanizing cement, which is allowed to dry. This must be thoroughly, not partly, dry. Then the proper patch is selected, the smaller size being sufficient for small patches, while in the case of large repairs, the patch should be from ½ to 1 inch larger all around than the hole. If this is not a prepared patch, one side should be cemented just as the tube was previously. If a prepared patch is used, the semi-cured side should be placed in, that is, with the sticky or uncured side toward the tube from the inside.

When the cement on the patch is just sticky enough, it should be inserted and the tube pressed down against it all around, slowly and carefully so as to get good adhesion. Next the cavity about the inside patch is filled with gum or pure rubber, preferably in sheet form as it comes for this purpose. This is filled in until the surface is flush. It is preferable to use a little vulcanizing cement to hold this rubber in place, particularly if a piece of sheet gum is cut to fill the hole.

Vulcanizing the Patch. The repair is now about half completed and is next vulcanized. The length of time, if steam is used, varies with the amount of steam pressure; if the portable gasoline or alcohol type of vulcanizer is applied the time varies with the temperature. As this time variation is so wide, it is impossible to give an invariable rule. Thick tubes require a little longer than thin ones, large patches longer than small ones, wide patches more than narrow, etc. The vulcanizing must be carefully and thoroughly done, and, as the success of the whole job depends upon this one process, the arrangement of the tube on the plate, of the soapstone on the new rubber and on the vulcanizer to prevent adhesion, of the wood or rubber pad above the patch, of the clamp and its pressure, should all have careful attention. With 60 pounds steam pressure available, from 10 to 12 minutes is about right, with 75 pounds from 8 to 10 minutes. In any case, the rubber should be cured just firm enough not to show a slight indentation from the point of a lead pencil. This is a good test to use at first, although after a short experience, the workman will be able to judge of the condition from the feeling, color, and general appearance of the patch.

When the size of the plate is small, the tubes should be held up above it out of the way, partly to allow the full use of the plate surface, but also to keep the tubes from being damaged.

Inserting New Section. *Preparing the Tubes.* In case the damage to the tube is too great to permit the use of a patch, for instance, in case a blowout makes a wide hole perhaps 7 inches or more long, in an otherwise good tube, it is advisable to cut out the damaged section and insert a new section in its place. Sometimes old tubes of the same size can be used for this, but, if not, sections can be purchased from the larger tire and rubber companies.

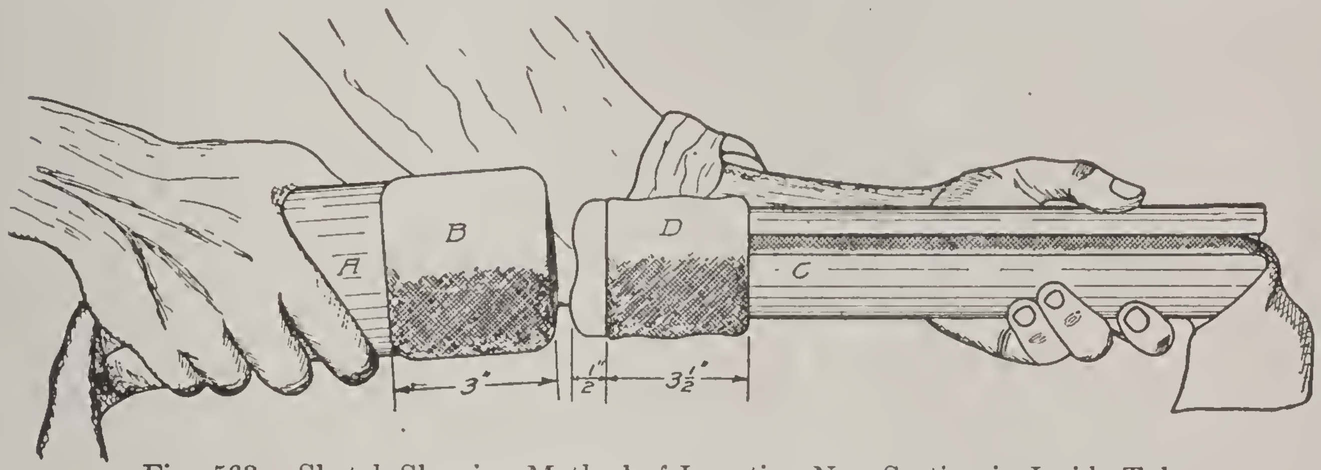


Fig. 563. Sketch Showing Method of Inserting New Section in Inside Tube

In the repair, proceed as follows: After cutting out the damaged section, bevel down the ends very carefully, using a mandrel to work on and a very sharp knife. As the appearance and, to a large extent, the value of the repair will depend upon these beveled ends, this should be done in a painstaking manner. Next select the tube section and cut it to size, that is, from 5 to 6 inches longer than the section which was cut out and which this patch is replacing. This allows $2\frac{1}{2}$ to 3 inches for the splice at each end. Bevel the ends of the tube as well, and, after beveling all four ends, roughen them with a wire brush or sandpaper.

Making the Splice. Having the tube and repair section beveled and buffed, the ends to be joined should be coated with one heavy or two light coats of acid-cure splicing cement. With the tube and patch properly placed on the mandrels—tube on the male and patch on the female—turn back the end to be repaired and the end to be applied as shown in Fig. 563. At *A* is shown the female mandrel on which is the patch *B*, turned back from the end of the mandrel about the right distance, say 3 to 3½ inches. On the male mandrel *C* the tube *D* has been turned back about 7 to 7½ inches, then turned back again on itself about 3 to 3½ inches.

Just as soon as the cement has dried thoroughly on the tube, apply a coat of acid to the patch and immediately place the two mandrel ends together and snap, blow, or push the end of the patch over on to the end of the tube. This frees the female mandrel, which can be laid aside. Immediately wind the patched portion (still on the male mandrel) with strips of muslin or inner tubing. In 15 to 20 minutes the cement will have formed a permanent union, the wrappings can be removed, and the tube withdrawn through the slot in the mandrel.

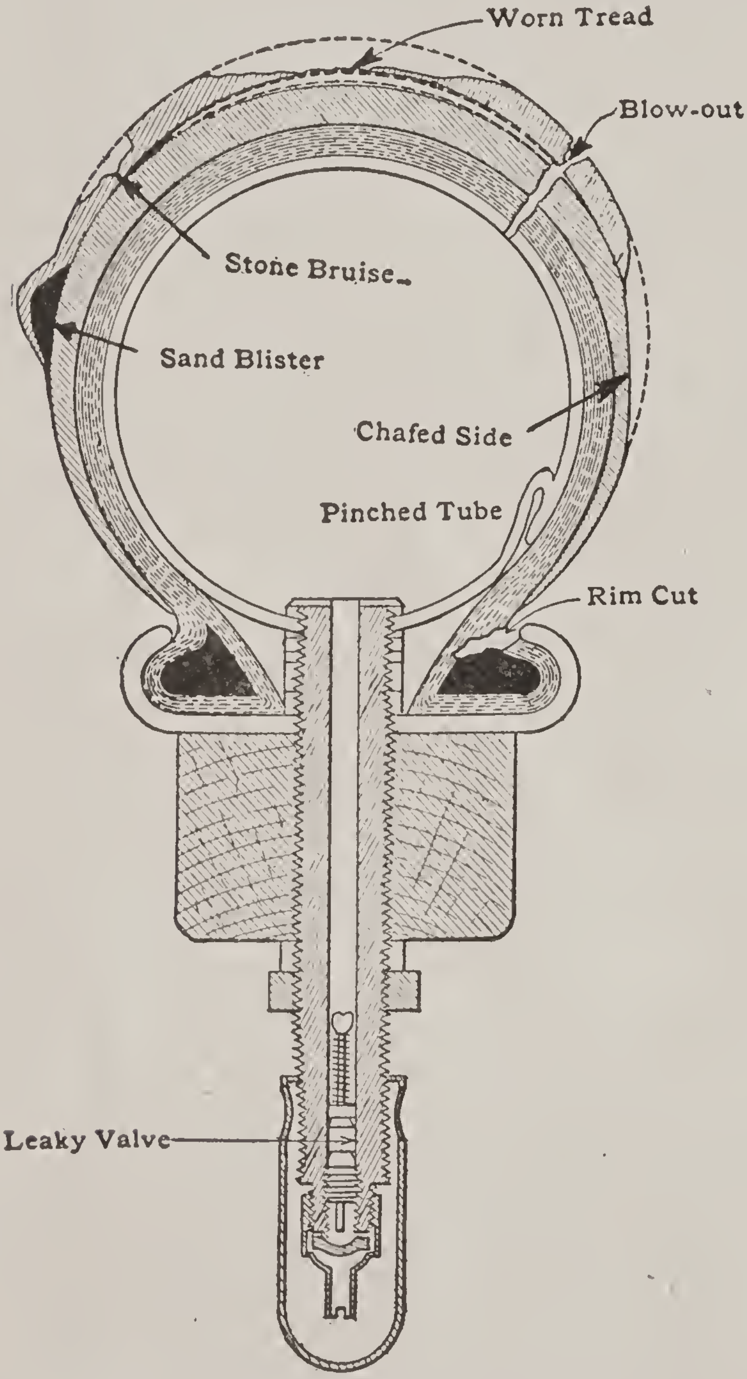


Fig. 564. Section of Tire, Showing Forms of Troubles

This done successfully, the whole operation is repeated for the other splice. If the splice does not cure together well, it indicates either that the acid supply is poor or else the splicing was not done quickly enough after applying the acid.

Outer Shoe, or Casing, Repairs

Classifying Troubles. Some of the common tire troubles—those of the inner-tube variety just discussed, and casing troubles as well—can be clearly shown by suitable illustrations. For example, a section through the tire showing how the troubles occur is sometimes very useful, as shown in Fig. 564. Here the pinched tube and blowout are indicated, the results of these on the inner tube and also their method of repair having just been described. These troubles together with punctures, leaky valves, and porous rubber in the tubes about cover the extent of inner tube troubles. Because of their more complex construction, casings have more numerous and more varied troubles, which, consequently, are more difficult to repair. The more common casing troubles are blisters, blowouts, rim cuts, and worn tread, the latter indicating the necessity for retreading. These will be described in order.

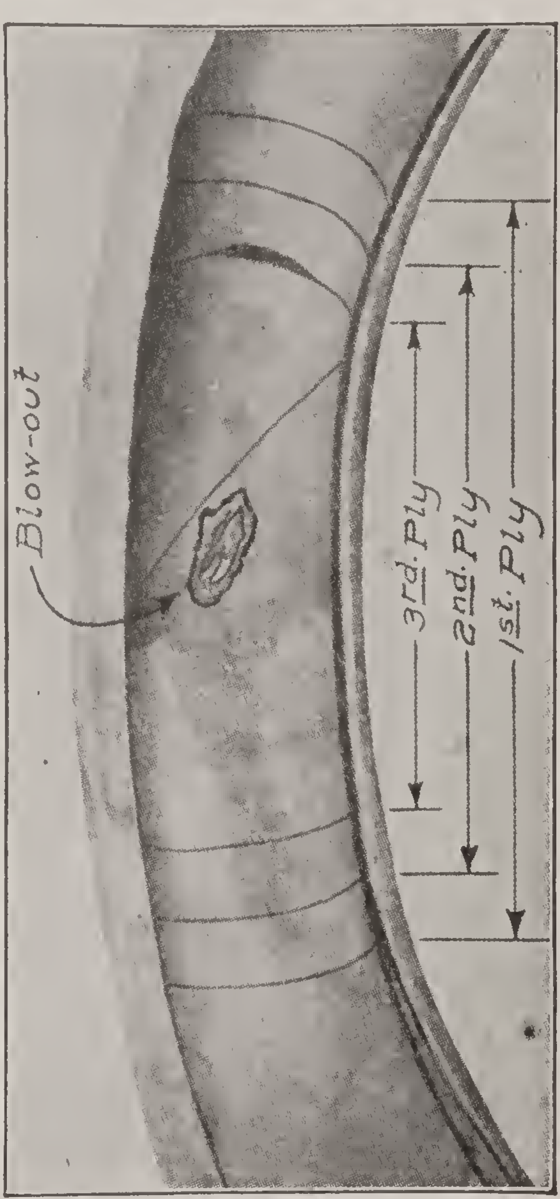


Fig. 565. Method of Preparing Layers of Fabricf or Patching Blowouts—Inside Method

Sand Blisters. The sand blister shown on the side of the tire, Fig. 564, is brought about by a small hole, such as an unfilled puncture hole, in combination with a portion of the tread coming loose on the casing near this hole. Particles of sand, road dust, dirt, etc., enter, or are forced into, this hole and move along the opening provided by the loose tread. Soon this becomes continuous and the amount of dirt within the break forces the surface rubber out in the form of a round knob known as a sand blister. This is cured by cutting open the blister with a sharp knife on the side toward the rim and picking out all dirt within. When the recess is thoroughly cleaned, the hole and the radial hole in the tire tread nearby should be filled with some form of self-curing rubber filler, a number of kinds of which are sold. The double benefit of this is to close the hole so that the trouble is not repeated and to keep out moisture which would ultimately loosen the entire tread.

Blowouts. The blowout, which is perhaps the most important casing repair, may be made in two ways: the inside method, in which the whole repair is effected on the inside; the combination inside and outside method.

Inside Repair Methods. Refer back to Fig. 564 for the general tire construction and to Fig. 565 for this particular case, the inside of the tire is held open by means of tire hooks and the inside fabric layers or plies removed for a liberal distance on each side of the opening. As shown in Fig. 565, a lesser amount of the second layer should be taken than of the first, and still less of the third and each subsequent one. On 3½- and 4-inch tires it is not advisable to remove more than two plies; on 4½-inch tires three, as shown; and on the larger sizes four plies. The edge of each layer of fabric should be beveled down thin, as well as the material directly around the blowout.

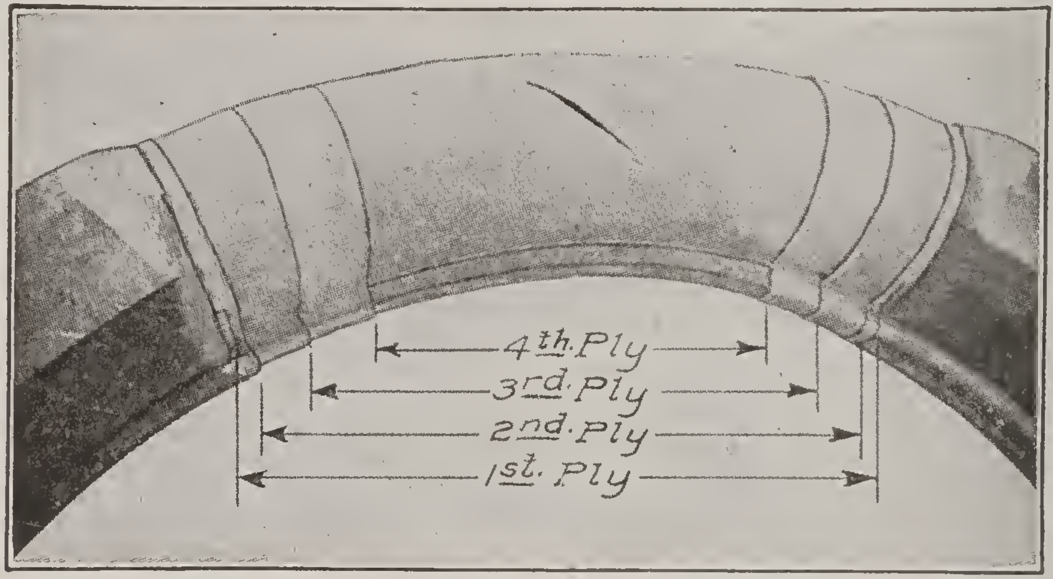


Fig. 566. Method of Preparing Fabric for Blow-Out Patch—Inside and Outside Method

Apply a coat of vulcanizing cement and when it has dried, say for an hour, apply another. When this has dried enough to be sticky or tacky, fill as much of the hole as possible with gum. When this is filled in level, apply the fabric patch. This is made up to match the fabric cutout, that is, if three layers are removed, it should consist of three plies stepped-up to match, and an extra last ply of bareback fabric unfrictioned on one side. This last layer should extend 3½ to 4 inches beyond the ends of the patch.

When this is properly applied and carefully smoothed down, the tire is placed in a sectional mold, clamped in place, perhaps wrapped with muslin strips to hold it tightly against the mold, and heat applied from the inside. This makes an excellent repair and a fairly quick and easy one, but it is not applicable for large blowouts; at least, it is not as effective as the inside and outside method.

Inside and Outside Method. In the inside and outside method, the material is removed from the outside, stepped down, and beveled in the same manner as for the method just described. Fig. 566 shows a tire with a medium size blowout, which has been stepped down for a sectional repair, four plies having been removed. The rule for the number of plies to remove is about the same as before, except that in the larger sizes this should depend more on the nature of the injury. It should be noted, however, that in this case the plies have all been removed right down to and including the bead. This is done to give the new fabric a better hold and to make a neater job and one that will fit the rim better. Give the whole surface two good coats of vulcanizing cement, allowing it to dry thoroughly.

Apply the same number of plies of building fabric as were removed, with the addition of chafing strips of light-weight fabric at the bead. Over this building fabric apply a thin sheet of cushion gum, slightly wider than the fabric breaker strip; then a thickness of fabric breaker strip over this; and then over this fabric another sheet of gum, slightly narrower than the previous sheet. All this, however, should be built up separately and applied as a unit and not one at a time, as described. These several plies should be well rolled together on the table. All edges should be carefully beveled off, especially the edges of the new gum where it meets the old, as it is likely to flow a little and leave a thin overlap which will soon pick loose.

No fabric is removed from the inside, but the hole is cleaned, its edges beveled, then filled with tread gum, and the inside reinforced with a small patch of building fabric; over this lay two plies of building fabric of considerable size. Now the whole casing is placed in a sectional mold, a surface plate applied to the outside, and heat applied both inside and outside. This will heat the tire clear through and make a good thorough job of curing.

Rim-Cut Repair. *Partial Cut.* To repair a partial rim cut, one or two plies of the old fabric are removed, unless it is severe, when three plies may be taken off. This is removed right down clean as explained under Blowout Repairs, and the cement and new materials applied in the same way, with the omission of the fabric breaker strip. However, care should be used to carry all building fabric layers not only down around the bead to the toe but up on the inside far enough to secure a good hold and ample reinforcement. If this should make the rim portion somewhat more bulky, remember it was a case of doing this or getting a new tire.

Complete Rim Cut. Where the rim cutting is continuous, the old side-wall rubber is removed up to the edges of the tread, and the old chafing strips and one ply of old fabric to about an inch above the beads removed also. Cut through the side-wall rubber all around, but be very careful not to cut into the fabric body, or carcass. The whole of the side wall and chafing strips can be removed in one operation. Apply two coats of cement and, after this is thoroughly dry, put on a patch consisting of one ply of building fabric, one ply of chafing strip, and a surface, or outside, ply of new tread gum. This is made on the table and the parts thoroughly rolled together. When completed, vulcanize in a sectional mold with sectional air bag and bead molds or endless air bag; apply to a split curing-rim wrap, and vulcanize in heater or kettle. The tire is repaired, but not vulcanized, and, with the ends of the three applied plies of material loosened to show, may be seen in Fig. 567.

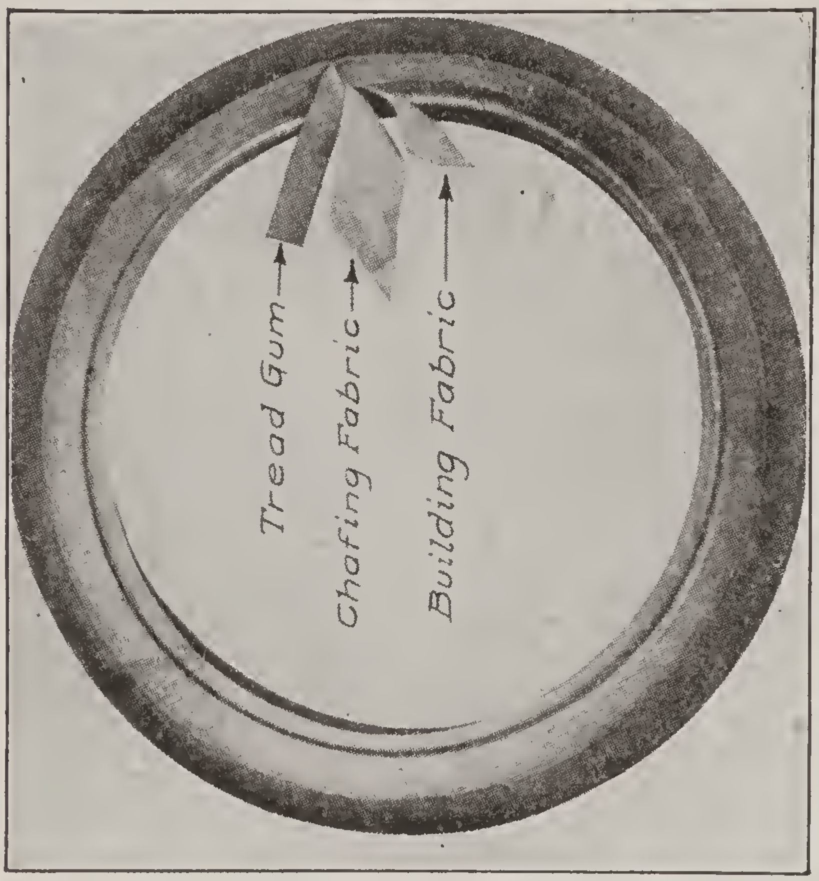


Fig. 567. Method of Handling Rim Cuts

Retreading. Retreading is a job which must be done very carefully, not only because of the job itself, but also because this is probably the most expensive single job which can be done to a tire, and the worker should make sure before starting that the wire warrants this expense. It should have good side walls and bead, and the fabric should be solid and not broken apart.

Repairing the Carcass. In the usual case, it is advisable to remove not only the surface rubber and fabric breaker strip, but also the cushion rubber beneath the breaker strip, that is, the tire should be cleaned off right down to the carcass, and the latter cleaned thoroughly. As the rubber sticks, a rotary wire brush will be found useful and quick. However, this should be used carefully so as not to gouge the carcass. After buffing, the loose particles of rubber should be removed with a whisk broom or dry piece of muslin. In this cleaning work the carcass should be kept clean and dry. Apply two coats of vulcanizing cement and allow both to dry; the first should be a light coat to soak into the surface fabric; the second should be a heavy coat.

Building Up the Tread. In building up the tread, it should not be made as heavy as the former tread, as the old worn and weakened carcass cannot carry as heavy a tread as when new. Furthermore, it takes longer to vulcanize a heavy tread and presents more opportunity for failure. In the building-up process, the proportioning of weights is important, and should be taken from the tabulation below, which represents years of experience in tire repairing:

Size of Case (in.)	Ply toward Fabric (in.)	Second Ply (in.)	Third Ply (in.)	Fourth Ply (in.)	Fifth Ply (in.)	Last Ply Over All	Complete Tread Consists of
3	2¾	3½				*See Note	3 plies
3½	2¾	3½	4¼			*See Note	4 plies
4	3¼	4	4¾			*See Note	4 plies
4½	4	4¾	5½			*See Note	4 plies
5	4¼	5	5¾	6½		*See Note	5 plies
5½	4¾	5½	6¼	7	7¾	*See Note	6 plies
6	5¼	6	6¾	7½	8¼	*See Note	6 plies

* Note—Determined by condition of case after buffing and cementing.

Size of Case (in.)	Width of Breaker Strip (in.)
3	1⅝
3½	2⅛
4	2½
4½	3
5	3⅝
5½	4
6	4½

This tread strip is built up on the table with exceeding care, all edges being rolled down carefully. When the strip has been prepared and the carcass is ready for it, one end should be centered on the carcass, and then the balance of the strip applied around the circumference, being careful to center it all around, as the workman in Fig. 568 is doing. After it has been applied all around, it should be rolled down carefully, all air pockets opened with a sharp pointed awl, and the gum at the edges of the plies rolled down with the corrugated stitcher. When ready, vulcanize in a kettle, using an endless air bag with tire applied to a split curing-rim, and wrapped—preferably double wrapped—all around.

Use of Reliner. Many a casing which appears good on the outside but which really is unsafe because of fabric breaks on the inside can be saved, or its life temporarily prolonged, by the application of a reliner. By this is not meant the prepared canvas and fabric reliner which can be put in dry, but a regular built-up strip of building fabric, vulcanized in place so as to be an integral part of the tire. For ordinary breaks, use a single ply of building fabric on a casing which has been entirely cleaned out and which has had two coats of vulcanizing cement thoroughly dried in. In the case of a bad break, use two plies of fabric, stepping them to fit; the under ply should be frictioned on two sides and coated on one, and the upper ply should be frictioned on one side only, the side toward the tube being bareback. Use an endless air bag for internal pressure, apply to a split rim, wrap, and vulcanize in a kettle from 35 to 45 minutes at a steam pressure of 40 pounds.

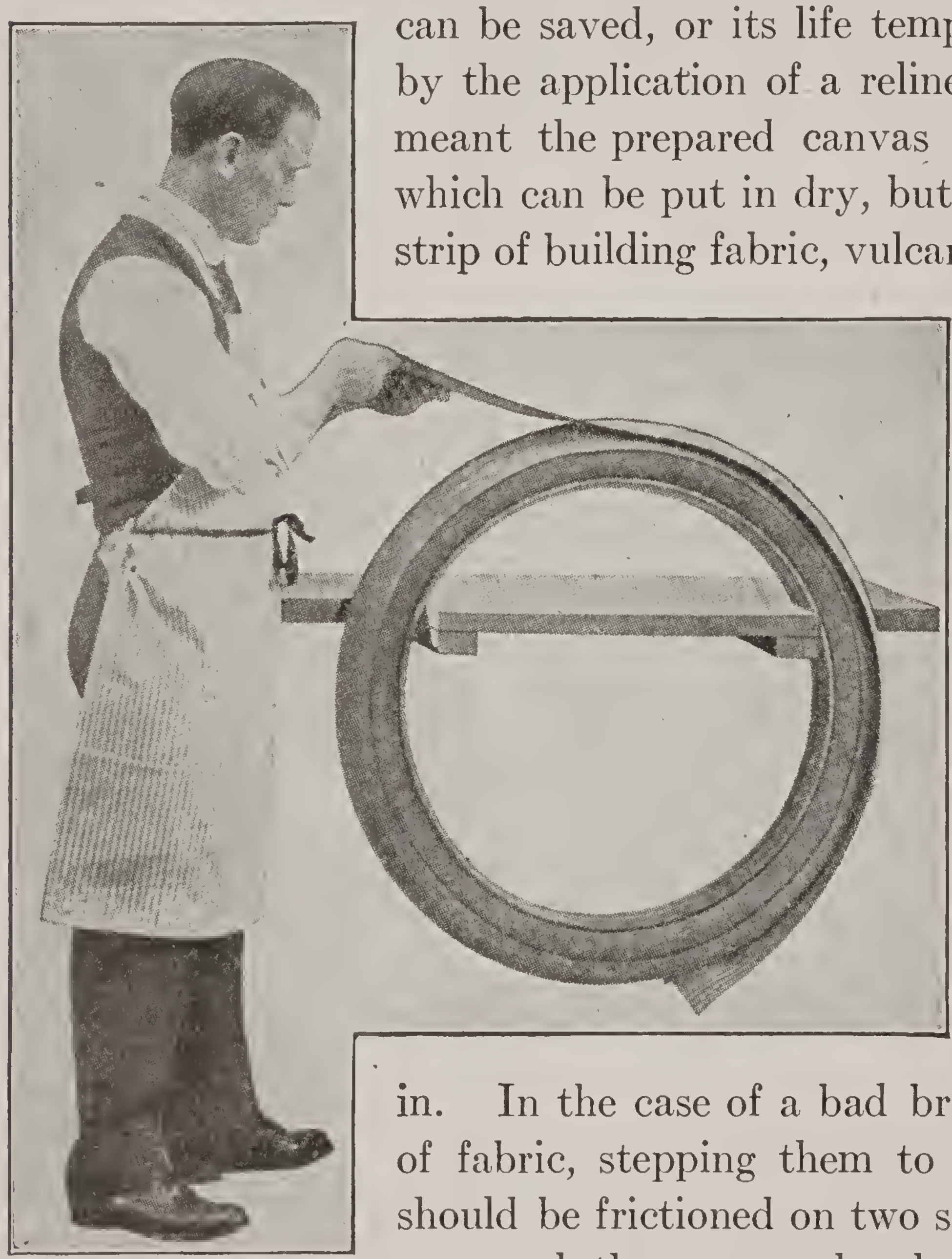


Fig. 568. New method of Putting on New Tread

Summary. By the application of parts of the foregoing instructions and the use of much common sense, coupled with a knowledge of the construction, use, and abuses of tires, the repair man will be able to handle any form of tire repair brought to him. In starting out, perhaps he could not do a better thing than to take an old tire apart to see just how it is constructed. This will give a much more clear idea than any number of diagrams, sketches, or photographs.

The tire repair man should remember, too, that this is no longer a game, but that, by means of scientific apparatus and the application of correct principles, it has been brought up to a high state of perfection; an expert can predict with reasonable accuracy what will happen in such and such a case, if this and that are not done. In short, the tire-repairing business within the last few years has been brought up to a stage where it, or any part of it, is a dependable operation. The tire repair man should handle all his work from this advanced point of view; it will pay the largest dividends in the long run.

SUMMARY OF INSTRUCTIONS

Q. What are the units comprising the final-drive group?

A. Universal joints; driving shaft; final gear reduction; axle-shaft differential; axle enclosure; torque rod, or tube, or substitute for this: radius rod, or tube, or substitute for this; brakes; wheels; and tires.

Q. Why are these called the final-drive group?

A. Because they constitute the final drive of the car, beyond the power-producing unit, the engine; the connecting and disconnecting unit, the clutch; and the speed-changing unit, the transmission.

Q. What is the function of the universal joint?

A. In the final-drive group, it is used to transmit power at an angle, as, from a horizontal-transmission shaft to an inclined-driving shaft.

Q. How does it do this?

A. The construction is such that the driving shaft is attached to one set of pins, while the driven shaft is attached to another, the axes of these intersecting in a common point. As the driven shaft can turn about its pins in one plane and, with the complete joint, about the driving shaft pins in another, as well as combinations of the two, complete freedom, or universal movement, is assured.

Q. What are the power losses in a universal?

A. In a well-designed and fitted universal joint, working practically at zero angle, there is no loss, but as the angle increases, the loss increases until at about 20 degrees, it may reach 2 or 3 per cent.

Q. Why is such a joint needed?

A. The final drive must be at the center of the rear axle, which is comparatively low, say 17 inches with 34-inch wheels or 18 inches with 36-inch wheels, while the power must originate at the engine which cannot be set as low as this, that is, the power must be generated at a higher level than that at which it is used. An inclined shaft and universal joints must be used somewhere in the system.

Q. What other considerations necessitate universal joints?

A. The engine level varies little, while the rear end of the chassis varies up and down through a considerable range. In addition, the rear end carries perhaps 85 per cent of the load and sustains greater road shocks because of this fact. The design is such as to keep the front, or engine, end as quiet and as nearly stationary as is possible. These considerations necessitate a flexible connection between the two ends, so that one can move frequently and through considerable distances, while the other moves seldom and through very small distances. In addition, the rear end must sustain considerable side sway, so that freedom in a sidewise direction is necessary. The only way in which these necessities can be obtained is through the use of universal joints.

Q. What is a slip joint?

A. One which will allow sliding, or slipping, of one part or shaft within the other. Thus, under certain restraining conditions the rise and fall of the rear end may mean approaching or receding of that end to and from the front portion. With a slip joint, this is made easy.

Q. What is the usual form of a slip joint?

A. Generally, this takes the form of a squared shaft within a squared-out housing, although sometimes the square is rounded off to give a slight universal action.

Q. What is the modern form of universal joint?

A. A thin flexible disc of steel, leather, fiber, or laminated fabric, with the driving shafts bolted to two opposite points and the drive shaft bolted to two others between them has been found to be much simpler, lighter, cheaper, and better than the average universal, although it allows only limited angular motion. The engine is being gradually lowered, while the rear wheels are constantly being increased in size; so the difference of level is not as great as it was, and there is less need for the full universal.

Q. What is the biggest advantage of these to the repair man?

A. They allow the removal of a driving shaft, or a unit on either side of such a joint much more quickly and easily, with less work, than any other form, similarly, in replacement after the repair is completed. In addition, they have no loose parts to be lost or mislaid with consequent trouble and delay of the work.

DRIVING SHAFTS

Q. What is the usual type of driving shaft?

A. The usual driving shaft is of small diameter and solid. Cold rolled steel is used on the lower priced cars, but forged steel machined at the ends (at least) is used on the better cars. On many of the most expensive machines, the shaft is fairly intricate in shape and is machined all over after forging, sometimes ground after hardening.

Q. What would be the advantage of a spring shaft?

A. Being flexible, it would cushion the shocks so that none of these reached the engine. Such shocks as are induced by jerking the throttle wide open, or stepping on the accelerator pedal suddenly or, on the other hand, a sudden application of the brakes.

Q. What is its real disadvantage?

A. Being small, the owner of the car and the driver would always mistrust it, and would not feel free to drive as they would with a larger and more dependable shaft.

Torque and Radius Rods

Q. What is torque?

A. Torque is turning effort, or force, applied to rotation, in the case of an automobile, to rotation of the driving shaft, and from it to the rear axle and wheels by means of the final reduction gears.

Q. What is a torque rod?

A. A rod, bar, or tube, provided to take, not the torque, but the equal opposite reaction from the torque application to the final drive.

Q. What is the manifestation of this torque reaction?

A. A tendency of the driving shaft and driving bevel gear to rotate up and around the bevel-driven gear in a counter-clockwise direction.

Q. How does the torque rod absorb this?

A. By extending this forward and attaching it to a frame cross-member at the front end and to the rear axle housing at the rear end, this counter-clockwise motion of the driving shaft is prevented.

Q. What is driving effort?

A. The force applied to the rear wheels tending to move the car forward. It is transmitted to the car, or frame of the car, as a push.

Q. How is this push transmitted to the frame?

A. In one of three ways; through special radius rods which transmit it directly to the frame; through a central tube which handles both torque and driving effort, transmitting this first to a frame cross-member, then to the main side members and through the springs, which are modified in attachment so as to take care of these extra stresses.

Q. Which is the best form?

A. The use of radius rods, one on each side, transmitting the stresses directly to the frame, is undoubtedly the best form, but also the most expensive, the heaviest, and includes the greatest number of parts.

Q. Which is the most simple form?

A. The use of the springs, the so-called Hotchkiss drive, but this also reduces the easy-riding qualities of the car because the springs, which should be flexible for easy riding, must be made somewhat rigid in order to transmit torque and driving reactions.

Q. Which is the cheapest?

A. Undoubtedly the use of the springs is the cheapest form, as it eliminates all additional parts, and simply necessitates a pivoted form of springing end in place of the usual shackle there.

FINAL DRIVES

Q. What are the usual methods of final drive?

A. Final drive is usually by one of these methods: roller chain, silent chain, spur gear, bevel gear, spiral bevel gear, worm and gear, rollers.

Q. Are all of these in use today?

A. All but the roller, although the two forms of chain drive have almost gone out of use for pleasure cars and are becoming less popular even for truck use.

Q. Which is most popular?

A. For pleasure-car use, the spiral bevel form, and for motor trucks, the worm.

Q. Why is the spiral bevel popular on pleasure cars?

A. Because of its many advantages. It is just as simple as the straight bevel, needs no additional parts, is more quiet, perhaps more efficient, is less likely to cut or wear, can be removed as readily, and has other minor advantages.

Q. Why is the worm popular for trucks?

A. It has all the needed qualities; it is efficient, silent, easy to handle, and allows bigger gear reductions than any other form. Furthermore, various gear reductions are interchangeable by changing other parts, and the worm has other advantages.

Q. Why is the worm not used more on pleasure cars?

A. Because it is not so well adapted to high speeds of 50 to 60 miles an hour and higher, which may be demanded, and because the large reduction between engine and rear axle, which is its biggest advantage, is not needed on pleasure cars.

Q. What are the three mostly used forms of rear axle?

A. The full floating, semi-floating, and three-quarter floating.

Q. Which is the best form?

A. From an engineering standpoint, the full floating is undoubtedly the best, but it is also the most complicated, with the largest number of parts, and the most expensive to construct.

Q. Which is the most simple form?

A. The semi-floating form is the most simple, but it lacks advantages which the majority of car owners want. It is the cheapest to make, but is made so through the lack of these advantages.

Q. Which is the compromise form?

A. The three-quarter floating form seems to offer a maximum number of advantages with the minimum of disadvantages. It has practically all the advantages of the full floating with less cost. It has all the advantages which the semi-floating lacks and costs but little more.

Q. Which is the most popular form?

A. The floating still has the greatest number of makers, but the three-quarter form is rapidly gaining in popularity and, in another year, will displace the full floating as the most popular, both as to the number of makers and as to the actual number of cars.

Q. Describe the internal-gear axle?

A. In this form a spur gear is used to drive an internal gear of larger diameter. This construction enables the separation of load carrying and power transmitting, so that one part of the axle can handle each.

Q. For what is this used mostly?

A. The internal-gear axle is used mainly on motor trucks, although a few heavy pleasure cars have been built with it.

Q. What is a differential?

A. A mechanical device for allowing the rear wheels to travel different distances when turning a curve or corner.

Q. How is this done?

A. By combinations, or nests, of gears and a divided rear axle, one-half being fixed to each half of the differential, with only the nests of gears connecting the two. As these are free to revolve as a unit, or stand still and have their gears revolve, the drive can either be transmitted all to one wheel, half to each wheel, or divided unequally.

Q. What is the usual differential form?

A. The usual differential gear is constructed with bevel or spur gears, the bevel form being more popular, the spur cheaper.

Q. What is undesirable in present differentials?

A. Present differentials have the disadvantage that they work for resistance not distance. This permits the wheel, which we do not want to slip, to slip on icy places so that the car cannot pull itself free, the differential making a bad matter worse.

Q. If the differential worked correctly, how could this be?

A. In such a case, since the differential worked only for difference in distance, and there was no difference in distance on an icy place, the power would be transmitted equally to the rear wheels. One would slip, but the other on firm ground would use its share of the power to pull the car off the icy place.

Q. How is it expected that this result will be attained?

A. By the use of helical gears, which, like the worm of a steering gear, are not reversible but will transmit power only in one direction.

Q. In addition to correct differentiation, what is it expected these differentials will do?

A. Eliminate skidding, always dangerous and always a possibility with present forms. The connection between skidding and present differentials has never been explained, but can be readily proved by the simple process of building a car without a differential.

Q. What forms of bearings are used in rear axles?

A. All the different kinds of bearings are used in rear axles: plain ball, plain straight solid roller, straight flexible roller, tapered roller, a few plain bronze bearings, ball-thrust forms, and others.

Q. Which form is most popular?

A. There is little choice between the two forms of roller and the ball bearing. In fact, the majority of axles use several different forms of bearings; so it is difficult to compare the work of the various bearing types.

Q. How can a broken spring clip be repaired?

A. A good substitute for a spring clip can be made from two flat plates and four bolts to reach from one plate to the other. The purpose of the spring clip is to hold the spring to the axle; this combination will do the same thing.

Q. How would you line up a rear axle?

A. With a try-square and plumb bob, working downward from the main frame, determine the distance from the rear end of the frame to the back side of the rear axle, on each side of the car. If the two do not agree exactly, the axle is out of square by the difference, or by half this difference on each side. Loosen the spring bolts, set the axle correctly, tighten the bolts, and check up the measurements again.

BRAKES

Q. What are the two general types of brakes?

A. The contracting-band, which is an external brake, and the internal-expanding shoe.

Q. How are these used?

A. There is no set rule; some designers use only the internal-expanding form, claiming this is more powerful and dependable; others use only the band, claiming this is cheaper to make and repair and just as good; still others take no side but use both forms.

Q. Has there ever been any agreement in relation to brakes?

A. Up to about a year ago, it was general practice to use the internal-expanding shoe brake for the emergency, or hand, brake. This was the case whether the band form was used for the foot, or running brake, or another expanding shoe.

Q. Does this rule hold now?

A. No. Many hand-operated brakes are of the contracting-band form, while many foot-operated forms, which would be considered the service, or running, brakes, are internal expanding. The tendency toward unit power plants is bringing back a shaft brake of the band type, operated by the hand lever.

Q. Where are the brakes generally located?

A. Except for the tendency just mentioned, the brakes have been located as much as possible in the rear wheels, on the assumption that this gave the most direct and thus the best application of the braking force.

Q. How are brakes arranged on the rear wheels?

A. When both brakes are placed on the rear wheels, practice is sharply divided into two camps. The one places the running brakes as a band form on the outside of the drum, claiming this makes a smaller lighter drum, a more compact group on the wheel, and less expensive because the drum is cheaper. The other places the two brakes side by side, making both of the internal-expanding shoe form inside a wide drum, claiming this is more effective, more powerful, and that the brakes are better protected against dirt, dust, and water because entirely enclosed, and thus are more effective and need less attention.

Q. What is the electric brake?

A. A new device which substitutes the rotation of an electric motor for hand or foot application of the brakes. This is put into action by a finger lever on the steering post, which makes contact, through suitable resistance, between the battery and the motor. When the motor rotates a cable is wound up and this pulls the brakes.

Q. Is this a powerful form?

A. Not only very powerful but also very quick to act, so that care must be used in applying it.

Q. What is the hydraulic brake?

A. A new form for heavy trucks and tractors, in which the use of an oil, which transmits power equally and without loss, is substituted for the usual rods and levers in the application of the brake. The construction is such that the driver can apply the brakes by a stroke of the hand lever, and if this does not give sufficient power to stop the truck, he can let the lever go forward and then pull it backward again; this action soes not release the brakes but does apply more force, that is, it can be worked continuously until sufficient power is applied to stop the vehicle, a peculiarity of this particular form.

Q. What is the vacuum brake?

A. A new form which utilizes the suction of the engine to create a vacuum in a special braking cylinder, the movement of a piston in which applies the brake. The amount of action depends on the amount of suction, that is, regulated by the amount the valve is opened, and this is dependent upon the pressure applied to the finger lever or toe button, whichever is used.

WHEELS

Q. What are the usual forms of pleasure=car wheels?

A. The plain wood form and the wire wheel comprise 99 per cent of all pleasure-car wheels; the wood forms about three-quarters and the wire about one-quarter of the total.

Q. What are the tendencies in wheel sizes?

A. On small cars the tendency is toward larger and larger sizes, but on the larger heavier cars the tendency is away from the very large sizes of a few years ago. The latter tendency has been brought about by the standardization of tire sizes, and the elimination of 38s, 40s, and larger sizes formerly made.

Q. What are the different forms of wire wheels?

A. The double-spoke form, which is lacking in lateral strength; the triple-spoke; and the quadruple-spoke. The two latter make up in strength what the former double-spoke form lacked. Except for number of spokes, these do not look any different to the casual observer.

Q. What is the sheet=steel wheel?

A. A form in which the whole wheel construction consists of a pair of sheet-steel members. These are given a slight taper, sometimes have holes through them for ventilation and to make them lighter, and frequently are painted to resemble wood-spoke wheels. The steel sheets are made thin enough to be flexible.

Q. What is the pressed=steel wheel?

A. A newer form in which a simulation of one-half the entire wheel spokes, hub and all, is pressed out of thin sheet steel, and a pair of these welded together so that the finished product has all the appearance of a wood wheel with the usual number of spokes, but without the rim which this construction eliminates.

Q. What are the usual truck wheel forms?

A. Most truck wheels are of heavy wood or cast steel. The latter do not weigh a great deal more than the former; because of the greater strength of the material, less of it can be used.

Q. Which is the most popular?

A. The wood form is still the most popular, despite its disadvantages for heavy truck use, but the steel form is gaining rapidly.

Q. What are the advantages of steel?

A. Greater strength, particularly to resist side stresses; better ventilation and removal of heat from the tires; more firm foundation for the tire so that it holds its shape better; and longer life at less cost.

Tires

Q. What are the general divisions of all tires?

A. Pneumatic, cushion, and solid.

Q. What is the principle of each?

A. The pneumatic tire has an interior air bag which is pumped full of air, the tire gaining its resiliency from this. The cushion tire is so constructed as to have a central air passage or other yielding space so that it gives a cushion effect under loads. The solid tire is a solid mass of rubber, its only give being the natural yield of the rubber.

Q. Is there a distinct field for each?

A. Yes. Pneumatics are used only on pleasure cars and the lighter trucks or delivery wagons; cushion tires are used mostly on slow-speed electric pleasure cars and a few light trucks; solid tires are used only on the heavy trucks.

Q. What is the big disadvantage of the pneumatic form?

A. Its liability to puncture or blow out, or loose its air otherwise, after which the tire is useless until the fault is mended; in fact, the tires are actually in the way, and running a deflated tire only cuts it to pieces.

Q. What are the divisions of pneumatic tires according to shape and method of holding?

A. While there are other forms, practically all tires today are in one of two classes, the clincher or the straight side.

Q. Describe the clincher type?

A. This is made with a bead or hard portion at the base, which forms a projection around which the clincher rim fits. The rim has the shape of a flattened U with the ends curled in, and the beads on the tire fit into these curled ends or clinches.

Q. What is the advantage of this?

A. The clincher form is held firmly on the rim, while the stiffness of the bead contributes more rigidity of form and permanence of shape to the whole tire.

Q. Describe the straight=side form.

A. This type of tire has no bead, the fabric forming the side walls being carried straight down to form the base without additional thickness of material.

Q. What are the advantages of this?

A. Its simplicity and lighter weight, with greater air space are the advantages of the straight-side form. In addition, in the newly standardized rim forms, the form of rim adapted to the straight-side tire is more simple, lighter in weight, and lower in cost than any other. It has been found by experience that the holding power of the beads was unnecessary as the inflated tire could not come off the wheel whether it had a bead or not, since its diameter at the base could not be increased in any possible way sufficiently to pass over the larger size rim.

Q. What is an oversize tire?

A. In the standardization of tires and rims, for each even tire size, which is called a standard, there is an oversize made which will fit on the same rim without any other changes.

Q. What is the difference between standard and oversize tires?

A. All standard tires are made in even inches of outside diameter, and all oversize tires are made in odd inches of outside diameter, so that the rule for oversizes is this: An oversize is one inch larger in diameter and ½ inch larger in cross-section, that is, the Ford size is 30 by 3½, the oversize for this, according to the rule, is 31 by 4; an average large car size is 36 by 4½, the oversize for this is 37 by 5.

Rims

Q. What are the general different rim forms?

A. Rims are generally divided into these forms: plain, which is no longer used; clincher, which is gradually going out; quick-detachable in its various forms; and demountable rims, now almost universal.

Q. What are the differences in these?

A. The clincher rim is a solid form, and the tire has to be stretched to get it on or off the rim. For this reason, it has to be made with a more or less yielding base, but even at that, tire removal is very difficult. The quick-detachable form is made with a locking ring on one side to replace the solid side of the clincher, so that tires can be applied easily. The demountable rim is a form which is used in combination with the others, this being a modification of the felloe of the wheel by which the entire tire and rim are removed in case of trouble, and then are replaced by another tire and rim which have been carried for this form.

Q. What are the advantages of this?

A. All roadside work is eliminated. When a puncture or blowout occurs, the driver simply jacks up his wheel, takes off tire and rim, and puts on the square tire and rim—the tire being inflated—lets down his car by means of the jack and drives off. The worn, or damaged tire, is carried at the rear in place of the spare, and is mended in the convenience and comfort of the garage or left at a tire repair station for that purpose. It saves work, time, and trouble at a time when these are of the greatest value to the owner. Given demountable rims, supplied on the car by the manufacturer, the car can be operated with all these conveniences without extra tire expense.

Q. How are demountable rims held in place on the wheels?

A. Nearly all demountables are held by means of wedges, with separate bolts to press these into place, or else a construction in which the bolt and wedge are combined.

TIRE REPAIRS

Q. What is vulcanization?

A. Vulcanization is the curing, or cooking, of raw rubber. By this curing it is more suitable for hard usage and its soft pliable character is changed without injuring its resiliency. If these were unchanged the tire would cut and would not wear.

Q. How is this accomplished?

A. By the application of heat in moderate quantities and in dry form. The heat is not applied directly but through metal. In the usual tire-curing mold the central space for the tire is surrounded by metal, with a hollow annular space outside of this into which the steam, which is generally used, is introduced. The heat from this steam penetrates the metal inside and vulcanizes the tire.

Q. Are all vulcanizers operated by steam?

A. Practically all the larger ones are, but many of the smaller forms of the portable type burn gasoline in the heating space, others use electric resistance coils.

Q. What is the advantage to the private owner of a vulcanizer?

A. When a tire is cut badly, he can apply raw rubber as a patch or repair, and then vulcanize this for the double purpose of curing and of uniting it with the older part of the tire. In this way, tire life is much prolonged at little expense.

Q. Is vulcanization profitable as a business for a repair shop?

A. It is said to be highly profitable, after suitable equipment has been purchased and a trade built up. It is said to be a more steady and stable business than any other, for, as soon as an owner has been convinced of the value of vulcanization of tubes and casings, he will bring in all his tire repairs.

Q. What is a sand blister?

A. A small opening in a casing, into which sand has entered and continues to enter until the outer surface is swelled up just like a blister. If neglected, this will ruin the casing.

Q. How should a sand blister be cared for?

A. By the immediate removal of the sand and the cleaning of the cavity, after which it should be filled with a tire-repairing cement or tire-filling compound. The sand can be removed by cutting a small hole in the underside of the blister with a sharp penknife.

INDEX

PAGE

A

- Adjustable crankshaft flanges 83
- Air, pre-heating for carburetor 198
- Air cooling 300
  - air jackets 301
  - blowers and fans 301
  - flanges, or fins 300
  - internal cooling and scavenging 301
- Air cushion 554
- Air and gasoline supply 106
  - auxiliary air valves 107
  - double carburetors for multi-cylinder motors 111
  - double-nozzle type 109
  - multiple-nozzle carburetors 112
  - nature of new development 110
  - use of by-pass 110
  - usual forms of auxiliary air-inlet valve 107
  - Venturi-tube mixing chamber 108
  - water-jacketing 106
- Air-inlet valve, auxiliary 107
- Air jackets 301
- Aluminum, cleaning 88
- Annular bearings, adjusting 421
- Anti-freezing solutions 299
- Automatic gear-cutting machine 423
- Auxiliary air valve 107
- Axle bearings 501
  - ball 502
  - classification 501
  - roller 502
- Axle pivots, inclining 446
- Axles, front 491

B

- Ball and Ball carburetor 145
- Ball bearings 334, 502
- Bead of tire 674
- Bearing balls, saving 417
- Bearings 76, 330, 369
  - ball bearings 334
  - bearing wear 77
  - clutch 369
  - combined radial and thrust bearing 337
  - crankshaft pounding 78
  - handy wrench 80
  - holding for bearing caps 79
  - plain bearings 331
  - roller bearings 332
  - test for tightness 78
  - types of bearings required for different locations 330

PAGE

- Becker gear-cutting machine 424
- Bennett air washer 185
- Bennett carburetor 181
- Bent rod, straightening 65
- Bevel gears 428, 454, 599
- Bevel pinion and sector steering gear 462
- Bevel type friction transmission 402
- Bilgram gear-planing machine 427
- Blowers 301
- Blowouts 693
  - inside and outside method 695
  - inside repair methods 694
- Brake adjustments 613
- Brake drums, truing 621
- Brake lining, stretching 620
- Brake lubrication 613
- Brake operation, methods of 610
- Brake troubles and repairs 617
  - dragging brakes 617
  - dummy brake drum useful 618
  - eliminating noises 620
  - to stop brake chattering 618
  - stretching brake lining 620
  - truing brake drums 621
- Brakes 604
  - brake adjustments 613
  - brake lubrication 613
  - classification 605
  - double-brake drum for safety 610
  - electric brakes 613
  - external-contracting brakes 605
  - function of brake 604
  - hydraulic brakes 614
  - internal-expanding brakes 606
  - methods of brake operation 610
  - recent developments 613
  - summary of instructions 699
  - troubles and repairs 617
  - vacuum brakes 615
- Brown and Sharpe gear-cutting machine 423
- Bushing removers 56
- By-pass, use of 110

C

- Cable drives 402
- Cadillac carburetor 173
- Camber complicates axle ends 496
- Cams 232
  - difficulties in making cams 244
  - friction 232
  - grinding increases accuracy 245
  - number of valves per cylinder 239

PAGE
Cams (continued)
  old way required more accurate inspection 245
  one cam for two valves influences shape 242
  typical valve actions 236
  what good modern practice shows 238
Camshaft 264, 271
  chain drive for 264
  twisted 271
Cantilever spring 534
Carbon deposits in cylinder 15, 31
  removal of 31
    carbon on fixed cylinder heads 31
    compressed air 33
    compression indicating gage 36
    liquid solvent 33
    removing carbon by scraping tools 33
Carburetor 15, 99
  classification 101
  defects in original not found in modern types 101
  developments in 110
  effect of heavier fuels 99
  floats 105
  function of carburetor 99
  needle valves 104
  throttle valves 103
Carburetor adjustment, general 193
  adjustments for heating water and air supply 194
  starving at high speeds 193
  tool for carburetor nozzles 193
Carburetor and carburetion 99
  adjustment of air and gasoline supply 106
  fuel supply 210
  inlet manifold design and construction 201
  kerosene and heavy fuel carburetors 177
  summary of instructions 218
  troubles and remedies 190
Carburetor on Ford cars 121
Carburetor troubles and remedies 190
Carter carburetor 164
Casing repairs 692
Cast axles 497
Chain drive for camshafts 264
Chain four-wheel drive 485
Changing tires 650
  speed changes due to changed tires 652
Chassis group 508
  characteristics of parts 508
  frames 509
  shock absorbers 549
  springs 530

PAGE
Chassis group (continued)
  summary of instructions 563
Circulation, water 293
  Cadillac system 296
  pumps 294
  thermosiphon 296
Clincher rims 654
Clutch forms in semi-, three-quarter, and full floating rear axles 584
Clutch group 351
  details of clutch operation 366
  summary of instructions 434
  types of clutches 351
Clutch operation, details of 366
  clutch accessibility 370
  clutch adjustment 370
  clutch bearings 369
  clutch lubrication 368
  clutch pedals 367
  gradual clutch release 367
  methods 366
Clutch troubles and remedies 370
  adjusting clutch pedals 378
  clutch spinning 375
  clutch troubles outside clutch 379
  cork inserts 375
  fierce clutch 374
  Ford clutch troubles 374
  handling clutch springs 373
  replacing clutch leathers 371
  slipping clutch 370
  summary 379
Clutches, types of 351
  classification 351
  cone clutch 352
  contracting-band clutch 354
  expanding-band, or ring, clutch 355
  disc clutch 356
  magnetic clutch 364
  requirements applying to all clutches 351
Coil-spring shock absorber 551
  combinations 552
  double-coil spring types 553
  springs alone 551
Commercial-car wheels 636
  cast-steel wheels 639
  miscellaneous wheel types 639
  modern status of spring wheel 642
  requisites 636
  wood wheels 637
Commercial-vehicle frame construction 523
Compression, poor 16
Cone clutch 352
Connecting rod 61
Connecting-rod bearings 63, 69
  adjustment of 69
    babbitting bearings 69

PAGE
Connecting-rod bearings (continued)
  adjustment of
    drilling thin shims 72
    kinks in adjusting bearings 69
    mandrel for lapping 72
    special sleeve replaces shims 71
Connecting-rod troubles and repairs 65
  adjustment of connecting-rod bearings 69
  classification of troubles 65
  straightening bent rod 65
Construction of motor-car, general outline of 2
Contracting-band clutch 354, 396
Cooling, internal 301
Cooling systems 286
  air cooling 300
  cooling troubles and adjustments 302
  water cooling 286
Cooling troubles and adjustments 302
  adjusting fans 302
  adjusting pumps 303
  cleaning 302
  replacements 302
  washing 302
Cord tires 653
Couple-Gear wheel 490
Crankcase 84
Crankcase arms and engine supports 87
Crankcase materials 87
Crankcase oil 329
Crankcase troubles and remedies 88
  cleaning aluminum 88
  general nature of troubles 88
  machining crankcase 89
  mending breaks 88
Crankshaft 72
Crankshaft and bearing troubles and remedies 76
  bearings 76
  crankshaft lapping 83
  handling shaft in machines 81
  holding crankshaft 81
  welding shafts and cases 84
Crankshaft bearings 75
Crankshaft and connecting-rod bearing shims 75
Crankshaft lapping 83
Cross-connecting rods 478
Cut-outs 286
Cycle in explosion motors 11
  four-stroke 11
  two-stroke 11
Cylinder bore 40
  checking up 40
  grinding 41
Cylinder and crankshaft sub-group 22
  connecting rods 61
  crankcases 84

PAGE
Cylinder and crankshaft sub-group (continued)
  crankshafts 72
  cylinder forms and construction 22
  pistons and accessories 48
Cylinder forms and construction 22
  cylinders classified as to fuel chambers or valves 28
  materials used 22
  method of casting cylinders 24
  methods of classifying cylinder forms 23
Cylinder heads 39
Cylinder lapping, methods of 41
Cylinder multiplication 12
Cylinder oil, mixing with fuel 330
Cylinder repairs 31
  checking up cylinder bore 40
  cylinder heads 39
  grinding out cylinder bore 41
  locating noises by means of stethoscope 37
  making gaskets 38
  methods of cylinder lapping 41
  removal of carbon 31
  repairing cracked water jackets 43
  replacing pistons in cylinders 46
  simple dead center indicator 42
  welding breaks in cylinders 43
  working in valve cages 46
Cylinders 28, 43
  classified 28
    I-head form 30
    L-head forms 28
    T-head forms 28
  welding 43

D

Dead center indicator 42
Demountable rim tire types 647
Demountable rims 660, 671
  comparison of continuous holding ring type with local wedge type 667
  local wedge type 660
  process of changing Baker local wedge type 662
  rim with straight split 666
  for wire wheels 671
Deppé gas generator 186
Differentials on rear axles, effect of 589
  improved forms 591
  possible elimination 593
Disc clutch 356
  floating discs 362
  greater power transmitted by surfaces not plane 362
  metal-to-metal dry-disc type 359
  multiple-disc clutches 358
  popularity 356

PAGE

- Disc clutch (continued)
  - simple types 357
  - two forms of same make 356
  - use of facings 360
- Disc individual clutch 396
- Double-brake drum for safety 610
- Double carburetors for multicylinder motors 111
- Double-chain drive 576
- Double-nozzle carburetor 109
- Drag link 474
- Driving reaction 579
- Drop forgings for front axles 498
- Dropped rear axle of full floating type 583
- Dummy brake drum useful 618
- Dunlop tire 645
  - demountable rim types 647
  - non-skid treads 647

E

- Electric brakes 613
- Electric car springs 541
- Electric drive 404, 405, 489
  - Couple-Gear type 490
- Electric generating clutch 364
- Electric transmissions 404, 405
- Electrically operated gears 393
- Elliott front axle 492
  - reversed Elliott 492
- Engine 15, 57
  - failure to start 15
  - speeding up old 57
- Engine group 3
  - carburetion sub-group 3
  - cooling system 5
  - cylinder and crankshaft sub-group 3
  - exhaust system 5
  - flywheel 7
  - ignition system 5
  - inlet and exhaust valves 5
  - lighting system 7
  - lubrication system 6
  - starting system 6
- Engine-group elements 11
- Engine repairs 16
- Engine troubles 15
  - deposits of carbon in cylinder 15
  - engine pulls on high speed but not on low speed 16
  - engine runs well on low speed but not on high speed 16
  - engine starts but stops after few revolutions 16
  - failure to start 15
  - knocking 15
  - knocking continues even after spark is properly adjusted 16
  - missing of explosions 15
  - poor compression 16

PAGE

- Engine troubles (continued)
  - popping in carburetor 15
- Ensign fuel converter 189
- Ensign heavy fuel carburetors 188
- Epicyclic, or planetary, gears 399
- Exhaust gases, importance of handling properly 279
- Exhaust manifolds, forms of 280
- Exhaust system 279
  - cut-outs 286
  - forms of exhaust manifolds 280
  - importance of handling exhaust gases properly 279
  - muffler 284
- Exhaust-valve setting 249
- Expanding-band clutch 355
- Exterior lubrication 305, 318
- External-contracting brakes 605

F

- Failure to start engine 15
- Fans 298, 301, 302
- Fellows gear shaper 424
- Fergus frame 516
- Filler cap 201
- Final-drive group 8, 569
  - brakes 604
  - driving shaft 8
  - rear axle 569
  - rear axle and differential 9
  - summary of instructions 699
  - tires 645
  - wheels 625
- Fins 300
- Flanges 300
- Flat-plate recoil springs 554
- Flexible joints 572
- Floating disc clutch 362
- Floats 105
- Flywheel characteristics 337
- Flywheel markings 246
- Flywheel sub-group 337
  - characteristics 337
  - importance 337
  - markings 339
  - methods of fastening 339
- Folding steering wheels 473
- Ford axles, checking up 603
- Ford cars, carburetors on 121
- Ford clutch troubles 374
- Ford planetary gears 400
- Ford spring 540
- Ford steering gear 465
- Forgings for front axles 498
- Four-cycle motor 11
- Four-stroke cycle 11
- Four-wheel driving, steering, and braking 482
  - advantages of four-wheel drive 489
  - chain four-wheel drive 485

PAGE
Four-wheel driving, steering, and braking (continued)
  Jeffery Quad 485
Frame bracing methods 529
Frame group 10
Frame troubles and repairs 525
  fracture 526
  frame bracing methods 529
  riveting frames 527
  sagging 525
Frames 508
  classes of frames 510
  effect on springs 513
  general characteristics 509
  pressed-steel frames 512
  rigid frame 513
  sub-frames 513
  summary of instructions 563
  tendency in design 511
  troubles and repairs 525
  types 515
Friction disc 401
  bevel type 402
  spur type 401
Frictional-plate shock absorber 550
Front-axle troubles and repairs 503
  alignment of front wheels troublesome 503
  spindle troubles and repairs 507
  straightening axle 505
  wobbling wheels 507
Front axles 491
  axle bearings 501
  materials 497
  troubles and repairs 503
  types 491
Front-wheel drive 480
  control 482
  difficulties of transmission 480
  friction-disc transmission 481
Fuel 99
  effect of heavier 99
  explosibility 8
Fuel feeding 210
Fuel line 217
  lock on 218
  obstructed 217
Fuel spray, methods of handling 106
Fuel supply 210
  fuel feeding 210
  piping and connections 215
  reserve tanks 216
  tank placing 210
Fuel system troubles and repairs 217
Full-elliptic spring 532
Full floating axle 581, 586

G

Gaskets, making 38
Gasoline 201

PAGE
Gasoline automobiles 1–349, 351–711
  bearings 330
  carburetors and carburetion 99
  chassis group 508
  clutch group 351
  cooling systems 286
  cylinder and crankshaft sub-group 22
  engine-group elements 11
  final-drive group 569
  flywheel sub-group 337
  general outline of construction 2
  introductory 1
  lubrication system 305
  steering group 445
  summary of instructions 91, 340
  transmission group 380
  valves and their mechanism 227
Gasoline line 201, 217
Gasoline railway cars, transmission needs of 395
Gasoline strainer 191
Gasoline tank, filling 191
Gear cases 87
Gear control 271
Gear-cutting machines, types of 421
  automatic 423
  Becker 424
  Bilgram 427
  Brown and Sharpe 423
  Fellows 424
  Gleason 425
  Whiton 422
Gear operation, noise in 409
Gear pitch and faces 433
Gear pullers 411
Gear shifting
  pneumatic system 395
  poor 412
Gear troubles 433
Gears 421
  types of gear-cutting machines 421
  types of gears in automobile 428
Gears in automobiles 428
  bevel 428
  gear pitch and faces 433
  gear troubles 433
  helical and herringbone 429
  spiral 430
  spiral bevels 431
  worm gears 432
Gleason gear planer 425
Gravity feeding 317
Gravity-return layout of tire repair equipment 685
Grease cups 330
Grease gun, mammoth 325
Greases 322

PAGE

H

H. & N. carburetor 167
Haywood vulcanizer 679
Heating charge 205
Heavier fuel, effect of 99
Heavy fuel carburetors 177
Helical gears 429
Herringbone gears 429
Hindley worm gear 464
Hoists and cranes 18
  commercial forms 20
  floor type of hoist support 19
  form of cradle 20
  home-made ceiling hoist 18
  portable engine stands 21
  Yale & Towne form 18
Holley all-fuel carburetor 128, 178
Holley carburetors 121, 177
Holley kerosene carburetor 177
Hotchkiss drive 536
Hydraulic brakes 614
Hydraulic clutches 364
Hydraulic gear 403
  Janney-Williams 403
  Manly 403
Hydraulic suspensions 557

I

I-head cylinder forms 30
Individual clutch 395
  general types used 395
  transmission adjustments 399
  transmission bearings 399
  transmission lubrication 398
  transmission operation 398
Individual pump pressure feeding 317
Inlet manifold design and construction 201
  changes 201, 206
  heating charge 205
  hot spots in manifolds 206
  inlet manifold troubles 209
Inlet valve, troubles with 262
Inner tube repairs 689
Inner tubes, improvement in 653
Interlocking devices for gears 391
Internal dogs, individual clutch using 395
Internal-expanding brakes 606
Internal-external gear individual clutch 397
Internal-gear drive for trucks 585
Internal cooling and scavenging 301
Interior lubrication 305

J

Jacking-up troubles 594
  substitute for jack 595
Janney-Williams hydraulic gear 403

PAGE

Jeffery Quad 485
Johnson carburetor 161

K

Kerosene carburetors 177
Kingston carburetor 121, 130
Knight motor, timing 276
Knight sleeve valves 272
Knocking in engine 15
Knox "F" carburetor 169
Knox tractor spring 538

L

L-head cylinder forms 28
Lemoine front axle 494
  inverted Lemoine 495
Locomobile spring 541
Lubrication 60, 305, 368, 398, 420, 480, 546, 594, 613
  curing excessive 60
  exterior 305, 318
  general 321
  gravity feeding 317
  individual pump pressure feeding 317
  interior 305
  neglect of 330
  principles of effective 323
  single-pump pressure feeding 308
  splash lubrication 318
  splash-pressure feeding 306
  troubles and remedies 325
    bending oil pipes 329
    care of lubricant in cold weather 325
    mammoth grease gun 325
    oil filtering outfit 328
    oil settling tanks 328
    oil tank and outfit for testing bearings 326

M

Magnetic clutch 364
Mandrel for turning pins 57
Manifold, changes in 201, 206
  for eights and twelves 204
  from fours to sixes 203
Manly hydraulic gear 403
Marmon self-lubricating axle 495
Marmon spring 537
Marvel carburetor 152
Master carburetor 133, 181
Metal-to-metal dry-disc clutch 359
Miller racing carburetor 135
Misfiring, causes of 199
Missing of explosions 15
Motor-car construction 2
  clutch group 7

PAGE
Motor-car construction (continued)
  engine group 3
  final-drive group 8
  frame group 10
  groups and parts 2
  steering group 9
  transmission group 7
Motor lubrication 305
Muffler 284
  troubles 286
Multiple-disc clutches 358, 379
Multiple-nozzle carburetors 112

N

Needle valve 104, 201
Needle valve stem, bent 191
Newcomb air-heated carburetor 151
Newcomb carburetor 148
Noisy bevel gears 599
Noisy tappet 390
Noisy valves 260
Non-leaking rings 59
Non-return layout of tire repair equipment 685
Non-skid treads 647
Nozzle, adjustment of 194

O

Oil barrels 326
Oil filtering outfit 328
Oil pipes, bending 329
Oil settling tanks 328
Oil tank and outfit for testing bearings 326
Oilless bearings 332
Oils and greases 322
  characteristics of good oils 322
  principles of effective lubrication 323
  testing oils for acid, etc. 323
Outer shoe repairs 692
  blowouts 693
  classifying troubles 692
  retreading 696
  rim-cut repair 695
  sand blisters 693
  summary 698
  use of reliner 698
Oversize tires, use of 649
Oxygen-adding devices 176

P

Packard bevel adjustment 599
Packard carburetor 172
Parker pressed-steel wheels 635
Parker rim-locking device 672
Parrett air cleaner 186
Patches on inner tubes 689

PAGE
Pedals, clutch 367, 378
Perlman rim patents 668
Piping and connections for fuel supply 215
Piston and accessories 48
  characteristics of piston rings 49
  piston construction 48
  piston pins 52
  types of piston rings 51
Piston pins 52
Piston and ring troubles and repairs 46, 53
  bushing removers 56
  curing excessive lubrication 60
  freeing wrist pins and bushings 55
  loosening seized pistons 55
  mandrel for turning pins 57
  mounting pistons on lathes 61
  non-leaking rings 59
  removal and replacement of pistons 46, 53
  testing size of new piston 59
  tracing ring knock 60
Piston rings 49
Plain bearings 331
Plain rim 654
Planetary gears 399
  Ford type 400
  method of action 399
Platform spring 533
Pleasure-car steering wheels 471
Pleasure-car wheels 624
  Parker pressed-steel wheels 635
  sheet-steel wheels 632
  wire wheels 628
  wood wheels 624
Pneumatic drive 404
Pneumatic system of gear shifting 395
Pneumatic tires 645
Poppet-valve gears 232
  cams 232
  repairing poppet valves and valve parts 252
  valve timing 246
Poppet valves and valve parts, repairing 252
  adjusting tension of valves 257
  chain drive for camshafts 264
  cleaning camshaft gears 270
  curing noisy tappet 252
  cutting valve-key slots 258
  grinding valves 258
  holding valve springs compressed 256
  noisy valves 260
  parts of valve system 265
  push rods and guides 266
  removing valve 252, 261
  removing valve spring 253
  troubles with inlet valves 262
  twisted camshafts 271

PAGE

- Poppet valves and valve parts, repairing (continued)
  - valve cage repairs 267
  - valve caps 269
  - valve enclosures 261
  - valve guides 268
  - valve timing gears 262
- Popping in carburetor 15
- Pressure feeding, individual pump 317
- Progressive gears 381
- Pumps, adjusting 303
- Punctures in tires, repairing 689
- Push rods and guides 266

Q

- Q.D. rim 654
- Quick-detachable rim 654
  - clincher forms 659
  - No. 2 657
  - type for straight sides 660

R

- Radial and thrust bearings 337
- Radiators and piping 289
  - modifications of cellular and tubular forms 292
  - types of cells 291
  - types of tubes 291
- Rayfield carburetor 141
- Rear axle carrying load and drive 582
- Rear-axle housings 589
- Rear-axle lubrication 594
- Rear-axle troubles and repairs 594
  - checking up Ford axles 603
  - jacking-up troubles 594
  - locating trouble 602
  - noisy bevel gears 599
  - rear axle 597
  - universal-joint housings 596
  - workstand equipment 595
- Rear axles 569
  - summary of instructions 699
  - transmission 569
  - troubles and repairs 594
  - types of rear axles 581
- Rear construction, disassembling and assembling 598
- Rear-end of frame, changes in 523
- Rear-wheel bearings 593
- Reliner, use of 698
- Repairs 16, 31, 43, 53, 65, 76, 88, 190, 217, 252, 302, 325
- Replacements 302
- Reserve tanks 216
- Retreading 696
  - building up tread 697
  - repairing carcass 696
- Retreading vulcanizers 684
- Reversed Elliott front axle 492

PAGE

- Rigid frame 513
- Rim-cut repair 695
  - complete rim cut 696
  - partial cut 695
- Ring clutch 355
- Ring knock, tracing 60
- Roller bearings 332, 502
- Rotating valves 278

S

- Sand blisters 693
- Scavenging 301
- Schebler carburetors 155
- Selective types of sliding gears 381, 382
  - four-speed type with direct drive on high 383
  - four-speed type with direct drive on third 385
- Semi-elliptic spring 531
- Semi-elliptic truck spring 538
- Semi-floating rear axle 581, 584
- Semi-reversible gear 467
- Seven-eighths floating rear axle 581
- Shackles for springs 544
- Shaft drive 573
- Shakespeare carburetor 171
- Shaler vulcanizer 679
- Shock absorbers 509, 549
  - air cushion 554
  - coil springs 551
  - flat-plate recoil springs 554
  - frictional-plate 550
  - function 549
  - general classes of absorbers 549
  - hydraulic suspensions 557
  - overload springs 558
  - summary of instructions 566
- Side-wall vulcanizer 683
- Silent-chain drive 577
- Single-disc individual clutch 396
- Single-pump pressure feeding 308
  - Marmon 312
  - methods of driving pumps 313
  - types of oil pumps 312
- Sliding gears 381
  - electrically operated gears 393
  - general method of operation 381
  - interlocking devices 391
  - modern selective types 382
  - pneumatic shifting system 395
  - progressive type 381
  - railway car needs 395
  - selective type 381
  - transmission location 385
- Sliding-sleeve valves 271
  - gear control 271
  - Knight sleeve valves 272
  - timing Knight motor 276
- Slip joints 571
- Small tool tire repair equipment 687

PAGE

Spark lever 474
Spindle troubles and repairs 507
Spiral bevel gear 431
Spiral gears 430
Splash lubrication 327
Spring clips, repair for broken 600
Spring troubles and remedies 546
  broken springs 548
  general hints on spring repairs 548
  lubrication 546
  tempering or resetting springs 548
Spring wheels 639
Springs 373, 509, 530
  adjusting spring hangers 544
  basis of classification 530
  cantilever 534
  clutch 373
  full-elliptic 532
  Hotchkiss drive 536
  platform 533
  semi-elliptic 531
  shackles and spring horns 544
  spring construction and materials 546
  spring lubrication 545
  summary of instructions 566
  three-quarter elliptic 532
  troubles and remedies 546
  unconventional types 537
  varying methods of attaching springs 542
Spur gears 428, 454
Spur type friction transmission 401
Steering-gear assembly troubles and repairs 469
  lost motion and backlash 469
  lost motion in wheel 469
Steering gears 330, 445
  action of wheels in turning 447
  Ford steering gear 465
  general characteristics of steering gears 450
  general requirements 445
  inclining axle pivots 446
  removing 468
  semi-reversible 467
  spur and level 454
  steering levers in front of axle 448
  troubles and remedies 469
  worm-gear 455
Steering group 9, 445
  front axles 491
  gears 445
  rod, or drag link 474
  special types of drive 480
  summary of instructions 558
  wheels 470
Steering knuckles 479
Steering levers in front of axle 448
Steering rod 474

PAGE

Steering rod (continued)
  cross-connecting, or tie, rods 478
  function and shape of steering knuckles 479
  lubrication of steering-gear assembly 480
  operation 474
  types of construction 476
Steering wheels 470
  different forms of hand wheels 470
  different wheels for commercial use 471
  throttle and spark levers 474
Stewart carburetor 158
Stromberg carburetors 112
Stromberg Ford carburetor 125
Sub-frames 513
Summary of instructions 91, 218, 340
Sunderman "Nitro" carburetor 170

T

T-head cylinder forms 28
Tables
  Royal Automobile Club's committee report on Knight engine 274
  timing regulation of American motors 234
  timing regulation of French motors 233
Tank placing 210
Tappet, noisy 252
Testing oils for acid, etc. 323
Testing size of new piston 59
Three-quarter elliptic spring 532
Three-quarter floating axle 581, 584, 588
Throttle lever 474
Throttle loose on shaft 192
Throttle valves 103
Thrust and radial bearing 337
Tie rods 478
Tillotson carburetor 168
Tire construction 673
  bead 674
  composition and manufacture 673
  tire valves 675
Tire improvements, recent 652
  cord tires 653
  inner tubes 653
  tire valves 652
Tire inflation pressures, proper 648
  use of standard pressure and oversize tires 649
Tire repair, materials used 689
Tire repair·equipment 677
  inside casing forms 683
  layouts of equipment 685
  materials 689

PAGE
Tire repair equipment (continued)
  retreading vulcanizers 684
  separate casing molds for patch work 681
  side-wall vulcanizer 683
  small tool equipment 687
  types of vulcanizing outfits 679
  vulcanization of tires for repair man 677
  vulcanizing kettles 682
Tire repairs 677
  inner tube repairs 689
  outer shoe, or casing, repairs 692
  repair equipment 677
Tire rims 654
  clincher 654
  demountable 666
  kinds 654
  Perlman rim patents 668
  other removable forms 671
  plain 654
  quick-detachable 654
  standard sizes 669
Tire valves 652, 675
  action 676
  improvement in 652
  leaky valves 676
Tires 645
  kinds 645
  pneumatic tires 645
  rims 654
  summary of instructions 699
  tire construction 673
  tire repairs 677
Tires and rims, standard sizes 669
Toquet Ford atomizer 125
Torque bar 577
Transmission 569
  driving reaction 579
  other flexible joints 572
  slip joints 571
  torque bar and its function 577
  types 572
  units in final drive 569
  universal joints 570
Transmission adjustments 399
Transmission bearings 399
Transmission group 7, 380
  classification 380
  freak drives 402
  friction disc 401
  gears 421
  individual clutch 395
  miscellaneous types 402
  planetary gears 399
  sliding gears 381
  summary of instructions 439
  troubles and repairs 409
Transmission location 385
  amidships alone or with clutch 387

PAGE
Transmission location (continued)
  amidships joined with driving shaft 387
  rear unit with rear axle 389
  unit with engine 385
Transmission lubrication 398, 420
Transmission operation 398
Transmission troubles and repairs 409
  care in diagnosis 412
  cleaning transmission gears 414
  gear pullers 411
  handy spring-tool 417
  heating 410
  lifting out transmissions 415
  noise in gear operation 409
  poor gear shifting 412
  possible troubles 418
  pressing gears on shafts 411
  saving balls 417
  summary 420
  transmission stands 415
  working in bearings 416
Troubles 15, 53, 65, 76, 88, 190, 209, 217, 302, 325
Truck types of steering wheels 471
Truss rods 597
Tubular axles 499
  drop-forged ends 499

U

Underpans, steel 521
Underslinging springs 543
Universal-joint housings 596
Universal joints 570

V

Vacuum brakes 615
Valve 227, 236, 252, 257
  action of 236
  adjusting tension 257
  grinding 258
  importance of 227
  noisy 260
  number per cylinder 239
  removing 252
  summary 227
  taking out 261
Valve cage 46, 267
Valve caps 269
Valve enclosures 261
Valve guides 268
Valve-key slots, cutting 258
Valve mechanism 227
  exhaust system 279
  poppet-valve gears 232
  rotating valves 278
  sliding-sleeve valves 271
Valve spring 253
  holding compressed 256

PAGE

Valve spring (continued)
  removing 253
  stretching and tempering 256
Valve-stem clearance 248
Valve system parts 265
Valve timing 246
  exhaust-valve setting 249
  relation of settings in each cylinder 249
  system applies to all types of motors 250
  valve-stem clearance 248
Valve timing gears 262
Venturi-tube mixing chamber 108
Vulcanization of tires 677
Vulcanizers, retreading 684
Vulcanizing kettles 682
Vulcanizing outfits 679
  Haywood 679
  inside casing forms 683
  retreading vulcanizers 684
  separate casing molds for patch work 681
  Shaler 679
  side-wall vulcanizer 683
  vulcanizing kettles 682

W

Water cooling 286
  anti-freezing solutions 299
  circulation 293
  fans 298
  radiators and piping 289

PAGE

Water-jacketing 106, 287
  built-on jackets 288
  internal jackets 287
  welded applied jackets 288
Water jackets, repairing cracked 43
Webber automatic carburetor 137
Welding 43, 84
Wheel pullers 643
Wheel sizes 622
  advantages of large wheels 622
Wheel troubles and repairs 643
Wheels 447, 622
  action in turning 447
  commercial-car wheels 636
  pleasure-car wheels 624
  summary of instructions 699
  troubles and repairs 643
  wheel sizes 622
Whiton gear-cutting machine 422
Winton spring 539
Workstand equipment 595
Worm gears 432, 455
Worm type steering gear 455
  Hindley worm gear 464
  worm and full gear 456
  worm and nut 458
  worm and partial gear 455
  worm and worm 461
Wrist pins and bushings, freeing 55

Z

Zenith carburetors 116

188 92

HECKMAN
BINDERY INC.
APR 92
N. MANCHESTER,
INDIANA 46962

LIBRARY OF CONGRESS

0 013 398 538 4